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Distribution of Plutonium and Americium beneath the 216-Z-1A Crib: A Status Report

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Research Department

February 1979

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DISTRIBUTION OF PLUTONIUM AND AMERICIUM BENEATH THE 216-Z-1A CRIB: A STATUS REPORT

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RESEARCH DEPARTMENT
RESEARCH AND ENGINEERING

February, 1979

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INDIVIDUAL CONTRIBUTORS

This document was produced through the efforts of many individuals. Key to the initiation of the project were the contributions made by R. E. Isaacson and D. J. Brown; their early research laid the groundwork for current Rockwell geo-environmental programs at Hanford. Planning and field work specific to the 216-Z-1A Crib characterization study were coordinated by S. M. Price and M. K. Additon. Initial drilling and containment techniques employed in the field were designed by H. A. Moulthrop; subsequent specialized drilling and sampling methods were innovated by C. T. Webster. Sampling work was carried out by plutonium finishing operators under the direction of G. L. Wagenaar. Data integration and interpretations were co-conducted by R. B. Kasper and S. M. Price with the support of M. K. Additon, R. M. Smith, and G. V. Last of the Earth Sciences Group. Pacific Northwest Laboratory personnel who also provided input into the document include W. C. Weimer, L. L. Ames, and A. R. Olsen.

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ABSTRACT

Past liquid waste disposal practices at the U. S. Department of Energy's Hanford site have included the discharge of actinide-bearing liquid waste directly to the ground via structures termed "cribs". A study to characterize the current distribution of plutonium and americium in sediments beneath one of these retired facilities, the 216-Z-1A Crib, has been conducted. To obtain distribution data, wells were drilled through and around the crib using specially developed containment and sampling techniques. Sediment samples collected during drilling were geologically characterized and analyzed for plutonium and americium content. The acquired data were used to construct geologic cross sections and isopleth cross sections of plutonium and americium concentrations with depth. Mechanisms which may have been responsible for the determined pattern of plutonium and americium distribution were also considered.

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DISTRIBUTION OF PLUTONIUM AND AMERICIUM BENEATH THE 216-Z-1A CRIB: A STATUS REPORT

INTRODUCTION

The U. S. Department of Energy's Hanford site is situated in the southeastern portion of the State of Washington near the confluence of the Columbia and Snake Rivers (Figure 1). Since 1943, the site has served as the location of reactor and chemical separation facilities for the production and purification of plutonium. The chemical processes used to purify plutonium result in the production of actinide-bearing waste liquid. Prior to 1973, effluent containing low concentrations of actinides (up to 100 uCi/ml of liquid) were discharged directly into sediments beneath Hanford's 200 East and 200 West Chemical Separations Areas (Figure 1) via underground structures collectively termed "cribs" (see Glossary). (1)

The development of a rational approach for the future disposition of retired actinide cribs is a major objective of the current Long Term Management of Low Level Wastes Program. As part of this program, an effort has been initiated to characterize the waste plume beneath the 216-Z-1A Crib, a facility which received an estimated 57 kilograms of plutonium.(2) The objectives of this characterization effort are to: 1) define the distribution of actinides beneath the 216-Z-1A Crib; 2) identify mechanisms by which actinides beneath the facility could be mobilized and released to the uncontrolled environment; and 3) provide a data base from which options for the permanent disposition of the crib can be developed.

Reported in this document is the status of an investigation to characterize the distribution of plutonium and americium in sediments beneath the 216-Z-1A Crib. In preparation, are separate documents which discuss: 1) drilling, sampling, and containment techniques developed for the 216-Z-1A Crib characterization effort; 2) the results of a nuclear reactivity assessment of the crib; and 3) analyses of groundwater samples

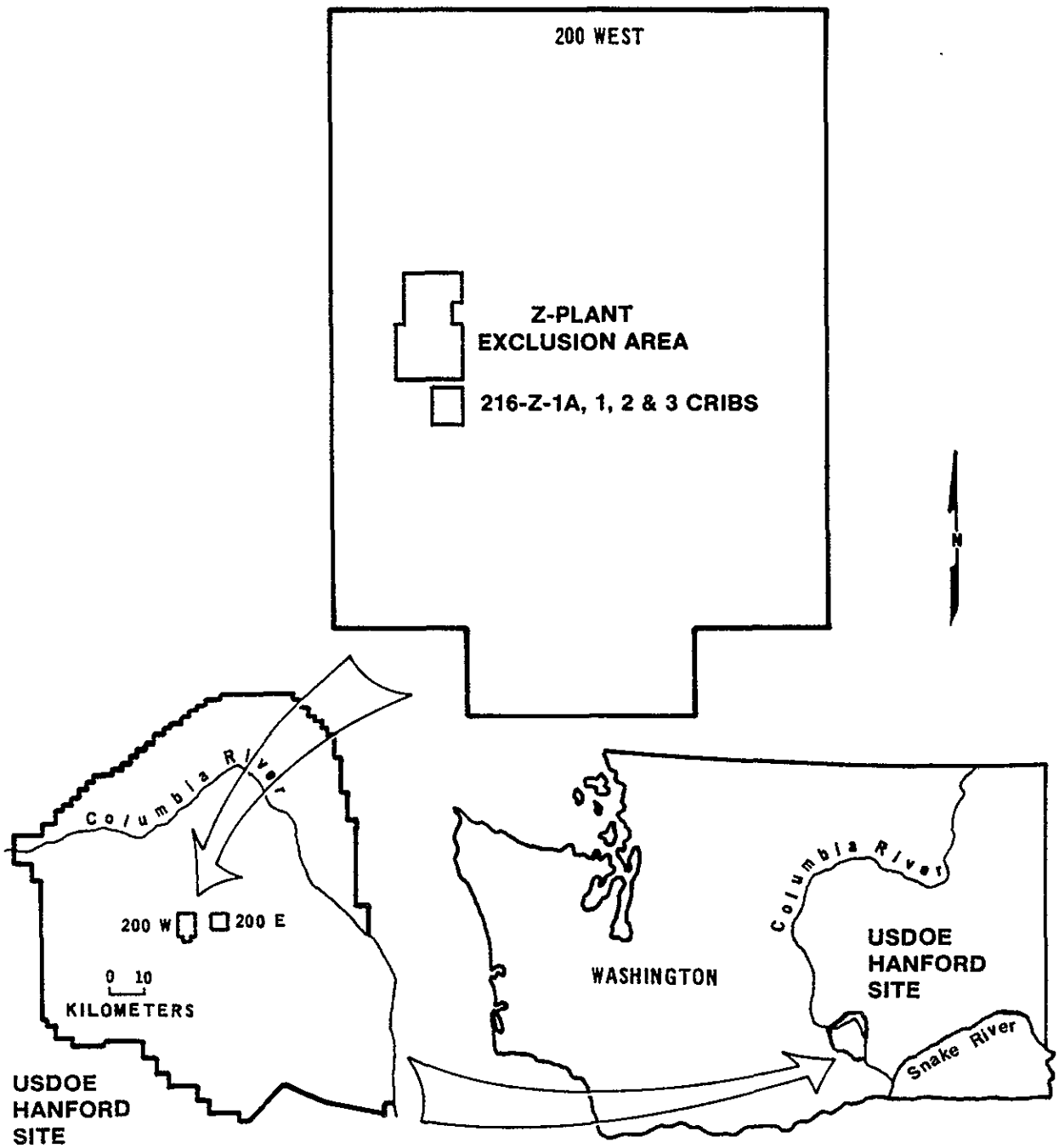

FIGURE 1 MAP OF HANFORD SITE

collected in the vicinity of the facility. The contents of these additional documents, and the results of ongoing and planned studies, will supplement the 216-Z-1A actinide distribution data discussed in the remainder of this text.

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SUMMARY

A study to characterize the current distribution of plutonium and americium in sediments beneath the retired 216-Z-1A Crib (Figure 2) has been conducted under the Long Term Management of Low Level Wastes Program. This crib was predominantly used to dispose of actinide-bearing, acidic waste liquid from the Plutonium Recovery Facility between 1964 and 1969. During this six-year period, the crib received approximately 6 X 10^6 liters of waste liquid containing an estimated total plutonium inventory of 57 kilograms. This waste was distributed to the ground through a buried "herringbone" pattern of pipe comprised of one 100-meter long central distributor pipe and fourteen 21-meter long laterals.

To obtain actinide distribution data, 16 characterization wells were drilled within the vicinity of the 216-Z-1A Crib. The location of these wells was based on a review of crib construction, waste disposal history, and available monitoring well data. The emplacement of characterization wells was carried out using drilling and containment techniques designed to prevent the release of actinides to the uncontrolled environment. Sample collection during drilling was based on geologic criteria and activity readings obtained by portable radiation survey instruments (see Glossary).

Selected samples from wells drilled through and in the vicinity of the 216-Z-1A Crib were quantitatively analyzed by granulometric and by actinide analytical techniques. The acquired data were used to construct geologic cross sections and isopleth cross sections of plutonium and americium concentrations with depth. Analytical results are graphically summarized in the concentration profiles included in Appendix B and in the activity isopleth maps included in Appendix D. A generalized illustration of the pattern of waste distribution with depth beneath the central distributor pipe is presented in Figure 3.

The highest concentration of $^{239-240}Pu$ (4 X 10^4 nCi/g)* and ^{241}Am (2.5 X 10^3 nCi/g) occurs in sediments located immediately beneath the crib, below the central distributor pipe. The concentration of actinides

*The unit "nCi/g" is an abbreviated form of nCi/gram of sediment (see Glossary).

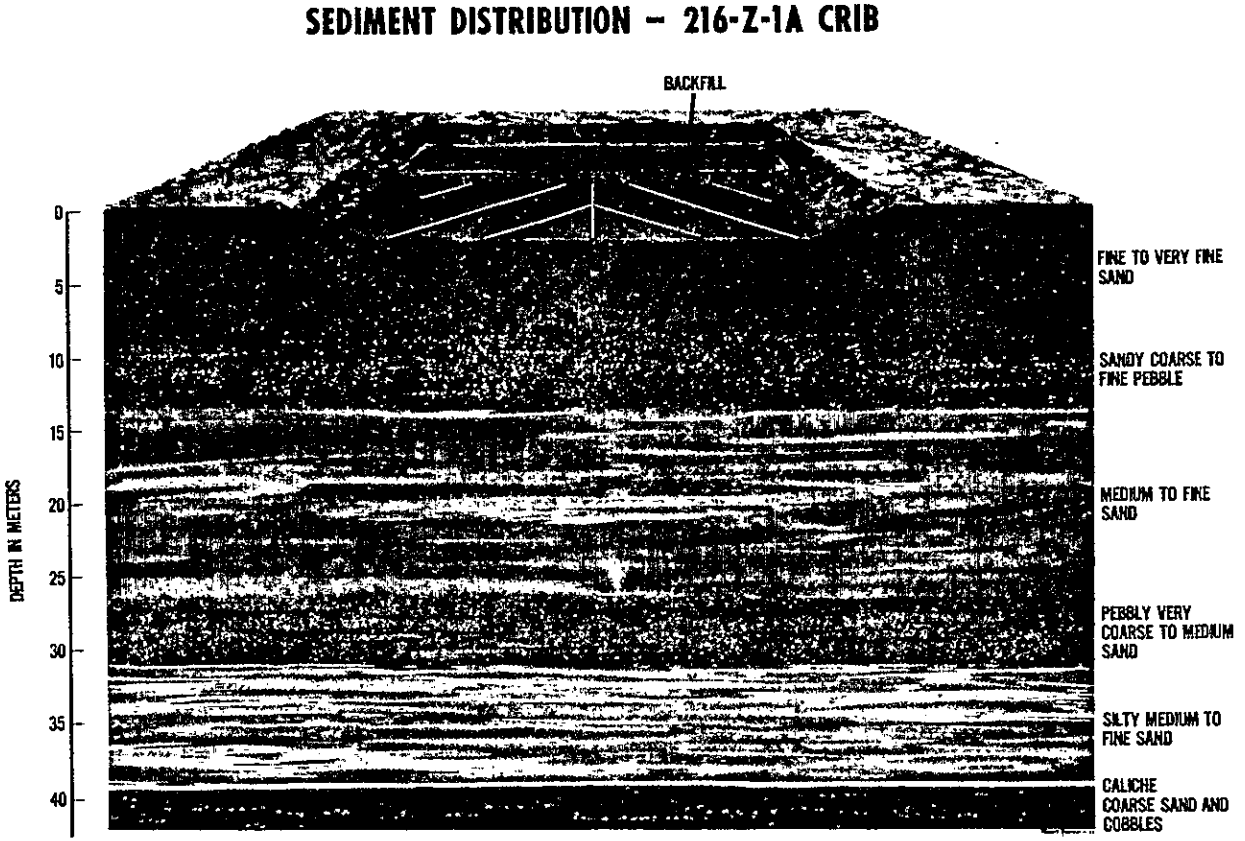
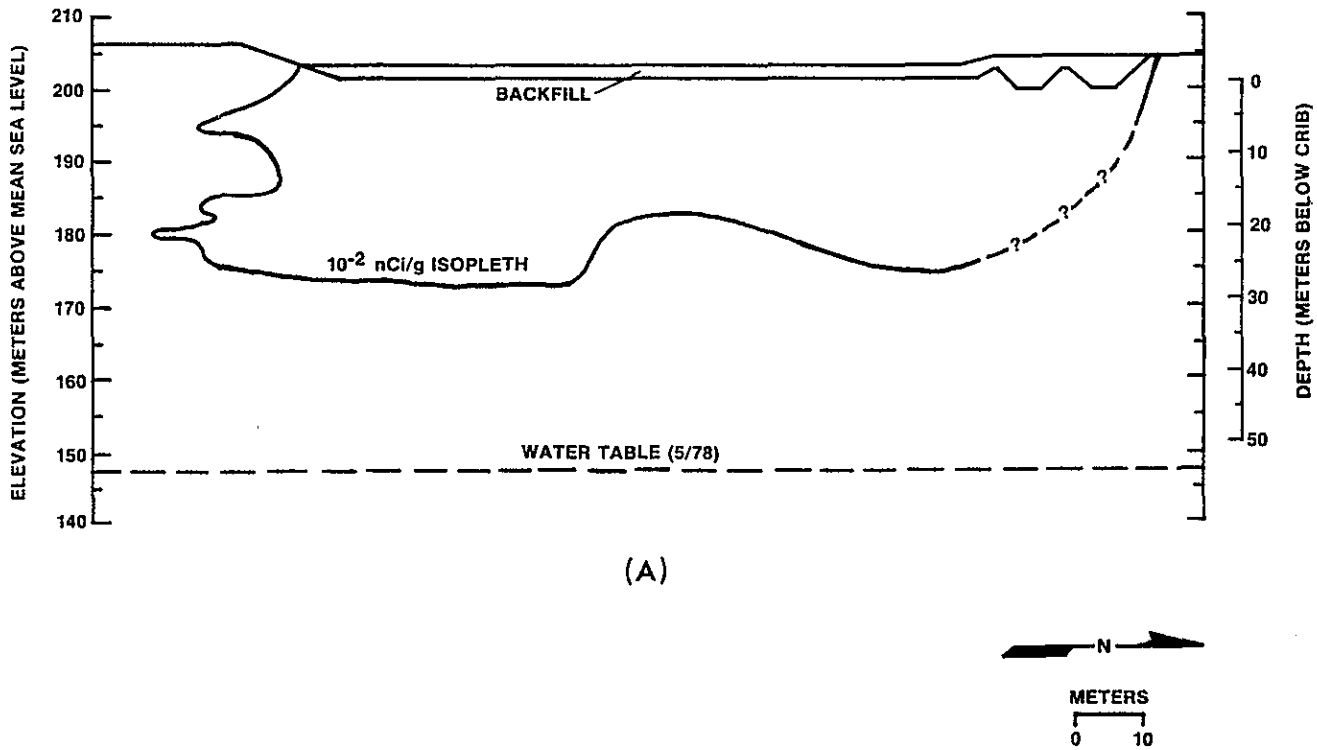
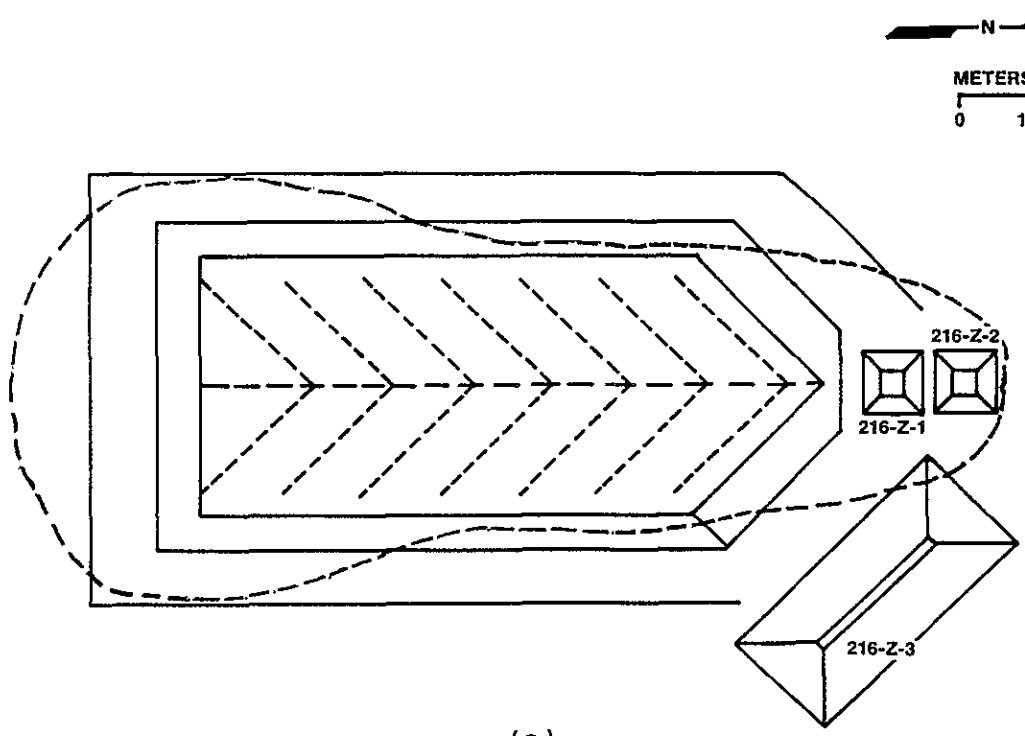


FIGURE 2 GRAPHIC REPRESENTATION OF THE 216-Z-1A CRIB AND UNDERLYING SEDIMENTS



(A)



(B)

FIGURE 3 GRAPHIC REPRESENTATION OF WASTE PLUME BENEATH THE 216-Z-1A CRIB
(A) NORTH-SOUTH CROSS SECTION THROUGH CENTER OF CRIB
(B) PLAN VIEW OF CRIB

in sediments generally decreases with depth beneath the waste distribution system, with the exception of silt-enriched horizons and boundary areas between major sedimentary units. The maximum vertical penetration of actinide contamination (defined by the 10^{-2} nCi/g isopleth) is located approximately 30 meters below the bottom of the crib, or approximately 30 meters above the groundwater table. The estimated lateral extent of contamination is located within a 10-meter wide zone encompassing the perimeter of the crib, as outlined on the plan view of the facility shown in Figure 3.

The pattern of waste distributed beneath the 216-Z-1A Crib is attributable to both physical and chemical mechanisms. Proposed mechanisms include: 1) the filtering of disposed PuO_2 particles from the waste liquid by sediments located immediately beneath the crib; 2) the effect of unsaturated flow within sediments; 3) a change in pH produced by silicate hydrolysis reactions between acidic waste liquid and the sediments; and 4) a change in pH produced by neutralization of the acidic waste liquid by $CaCO_3$ in the sediments. Studies to evaluate more fully the applicability of the proposed distributional controls and to assess the migration potential of actinides beneath the 216-Z-1A Crib are planned.

CRIB HISTORY

The 216-Z-1A Crib is located in the 200 West Chemical Separations Area immediately south of the Z-Plant exclusion area (Figure 1). The crib was constructed in 1949 and was used between 1949 and 1959 to receive the overflow of liquid waste from the 216-Z-1, 216-Z-2, and 216-Z-3 Cribs (Figure 4). Use of all four facilities was discontinued at the end of this ten-year time period.(3) Waste was routed directly to the 216-Z-1A Crib in 1964. During the following five-year period, the facility received approximately 6.2×10^6 liters of acidic waste liquid containing an estimated cumulative plutonium inventory of 57 kilograms.(2) The 216-Z-1A Crib was permanently retired from service in 1969.(3)

CRIB CONSTRUCTION

An illustration of the 216-Z-1A Crib is included as Figure 5. Construction of the crib was initiated with a rectangular excavation having a surface dimension of approximately 60 by 110 meters. The side walls of the 5.8-meter deep excavation were sloped inward, resulting in a floor dimension for the facility of approximately 35 by 84 meters. The floor of the excavation was covered by a 1.2-meter thick cobble layer with a minimum north to south surface slope of 1 percent. A herringbone pattern of 20-centimeter diameter clay pipe, comprised of a 79-meter long central distributor pipe and fourteen 21-meter long secondary laterals, was placed on this cobble layer. The 30 by 79 meter rectangular area covered by the piping system was then overlain with 15 centimeters of cobbles and 1.5 meters of sand and gravel. Prior to reactivation of the 216-Z-1A Crib in 1964, a sheet of polyethelene covered by 30 centimeters of sand and gravel was also added to the facility. This modification was made as a precautionary measure to prevent the upward migration of waste liquid.

Engineering drawings illustrating the specific construction of the vitrified clay pipe are incomplete. To determine the pattern of liquid waste discharge, portions of the central distributor pipe and first east

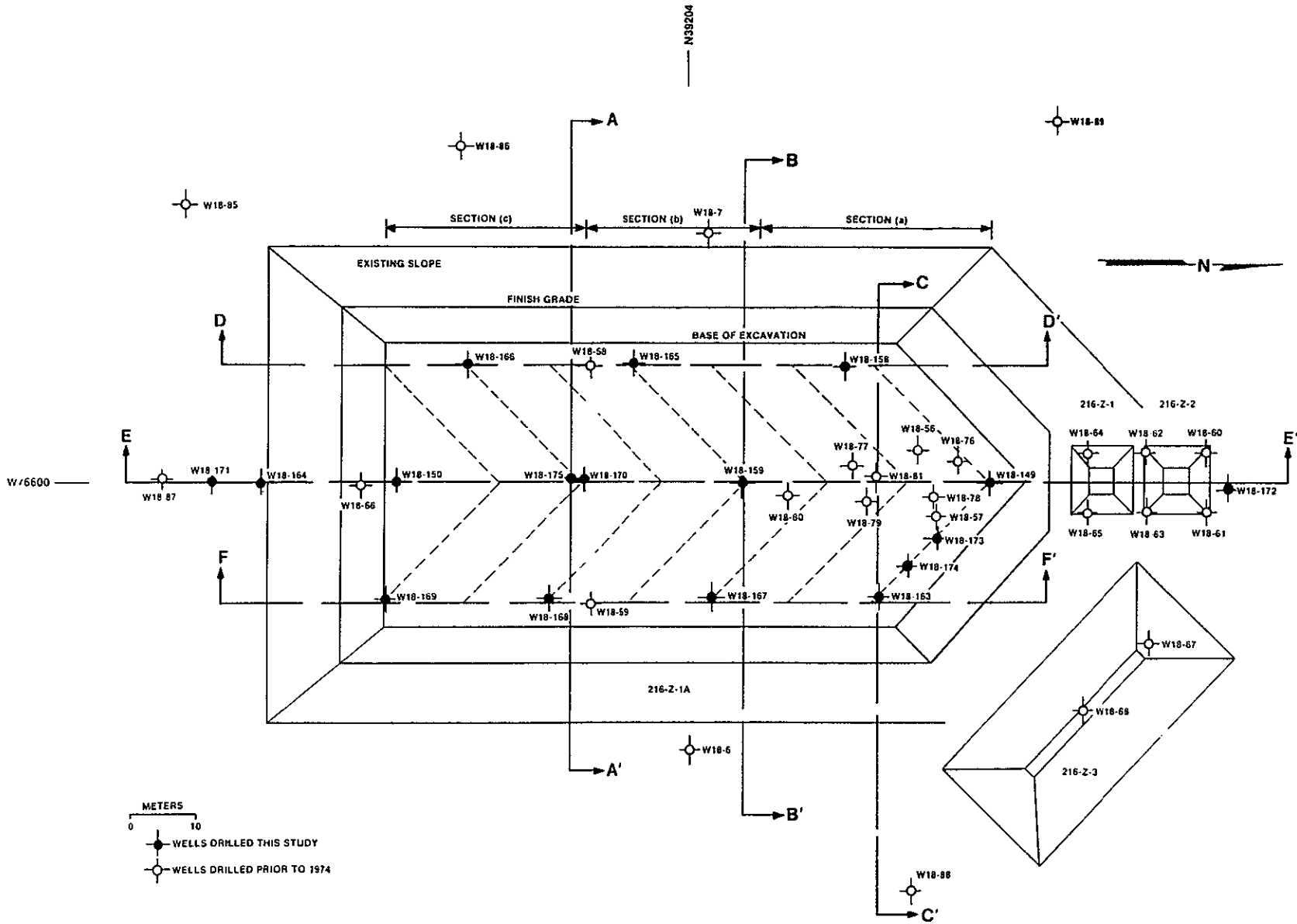


FIGURE 4 216-Z-1A, 216-Z-1, 216-Z-2, and 216-Z-3 PLOT PLAN

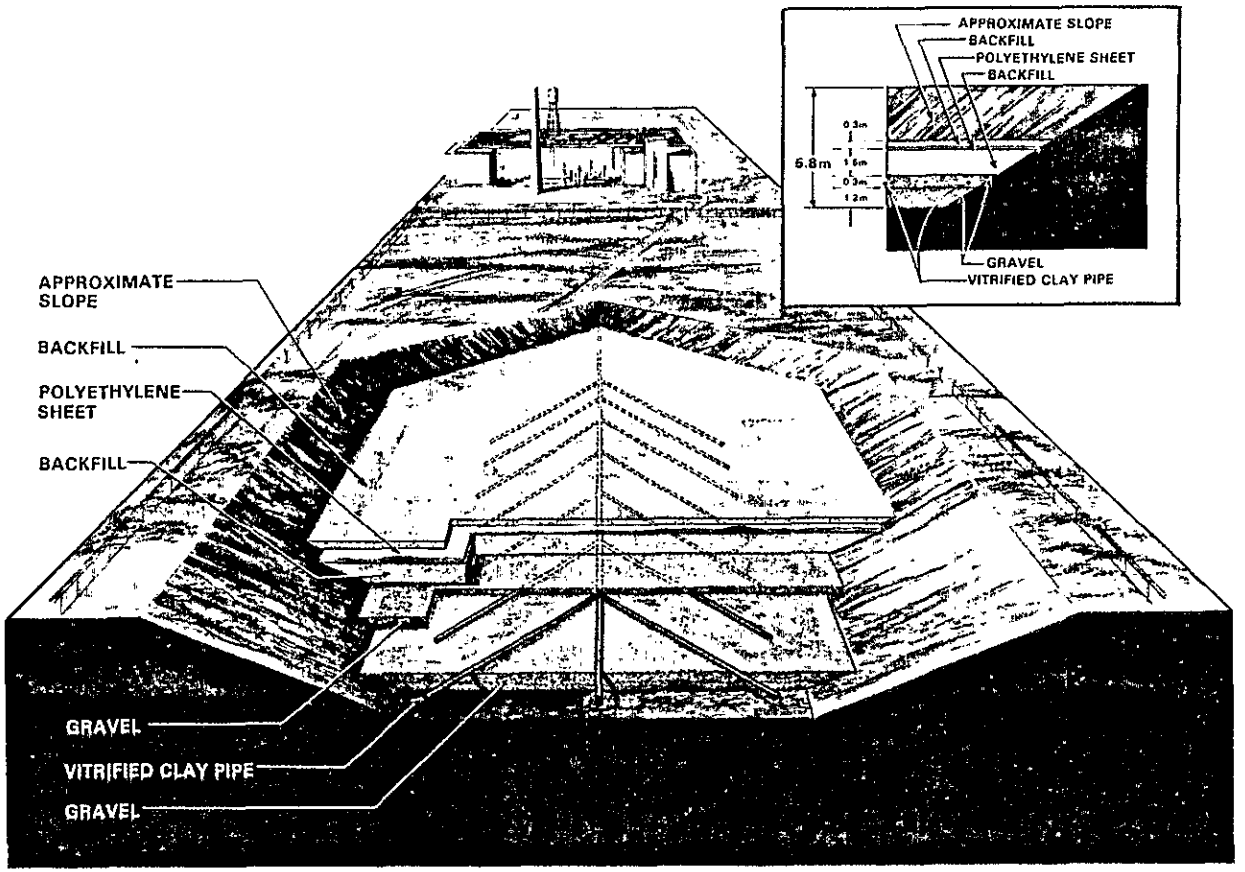


FIGURE 5 216-Z-1A CRIB CONSTRUCTION DETAILS

lateral were excavated during the crib characterization effort. Excavations of the central distributor pipe showed that the pipe is a continuous line, without perforations. In contrast, an excavation at the end of the first east lateral showed that the clay pipe is divided into 0.3-meter long segments (Figure 6). Based on the observations made during these excavations, it can be assumed that the clay piping system was constructed to distribute liquid waste primarily through the gaps along the 14 segmented secondary laterals.

WASTE DISPOSAL

The 216-Z-1A Crib received overflow waste from the 216-Z-1 and 216-Z-2 Cribs between 1949 and 1952 and from the 216-Z-3 Crib between 1952 and 1959 (Figure 4). The waste stream consisted of process waste and analytical and development laboratory waste from Z-Plant via the 241-Z-361 Settling Tank.[3] The estimated overflow waste inventory received by the 216-Z-1A Crib is listed in Table 1.

TABLE 1

ESTIMATED RADIONUCLIDE CONTENT OF LIQUID WASTE RELEASED TO THE 216-Z-1A CRIB BETWEEN 1949 AND 1959[2]

RADIONUCLIDE	TOTAL AMOUNT DISCHARGED THROUGH 1959
Pu, g	5.0×10^{1}
Beta, Ci	2.28×10^{1}
^{90}Sr, Ci	$<1.0 \times 10^{-1}$
^{106}Ru, Ci	1.0×10^{1}
^{137}Cs, Ci	$<1.0 \times 10^{-1}$
^{60}Co, Ci	$<1.0 \times 10^{-1}$
U, Kg	$<5.0 \times 10^{-2}$
(Volume, Liters)	1.0×10^{6}

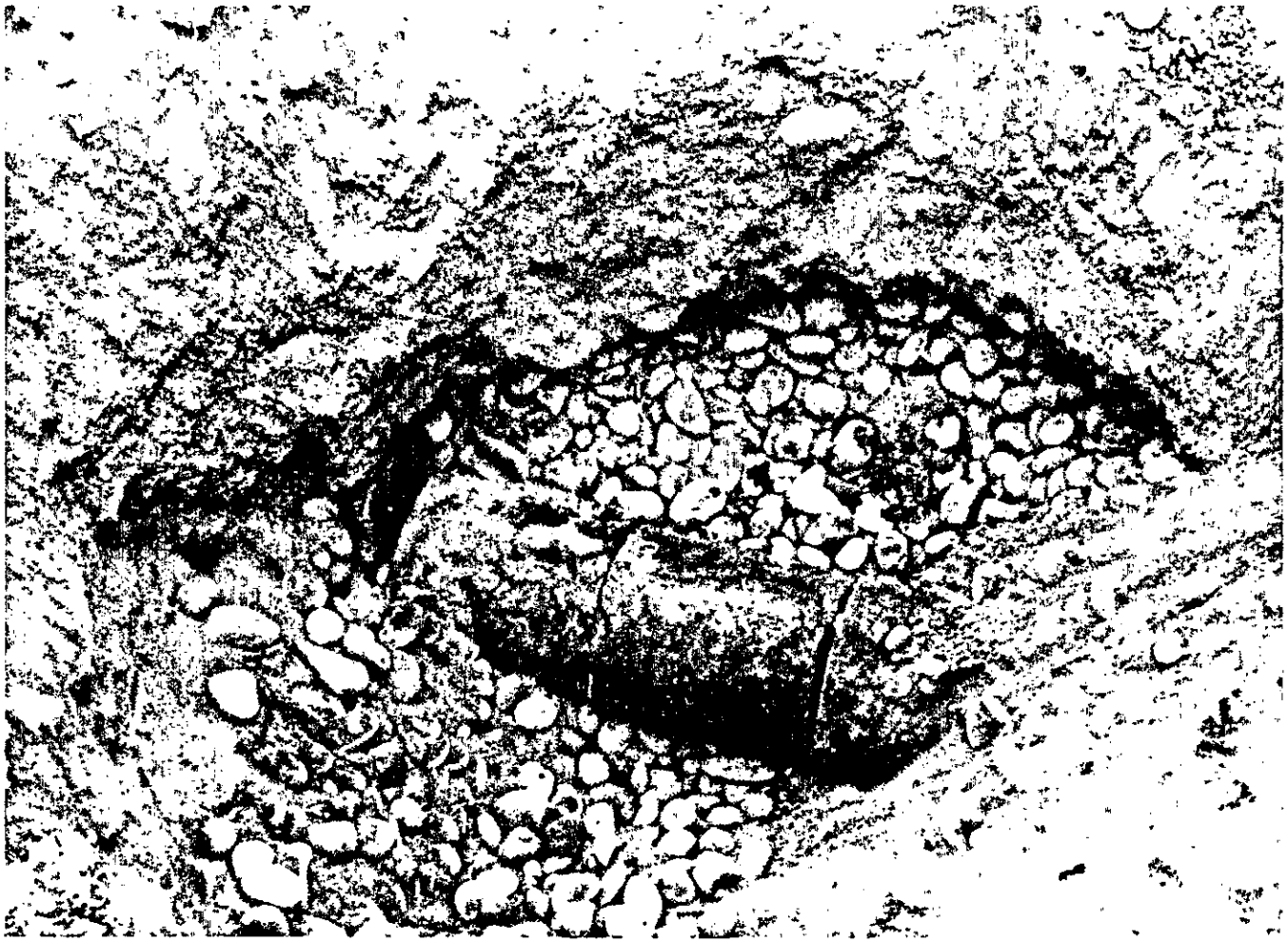


FIGURE 6 EXCAVATION OF LATERAL SHOWING 0.3-METER LONG SECTIONS OF VITRIFIED CLAY PIPE

Following deactivation of the 216-Z-3 Crib in 1959, the 216-Z-1A Crib was removed from service.

In 1964, the 216-Z-1A Crib was reactivated to receive aqueous and organic waste from the Plutonium Reclamation Facility located in Z-Plant[3] (Figure 1). The estimated composition of acidic aqueous waste (AAW) released from this facility is given in Table 2. In general, the acidic waste was a concentrated solution of nitrates. In addition to the aqueous phase, organic liquid was also discharged to the crib. The organics consisted mainly of carbon tetrachloride (CCl_4) and tributylphosphate ($(C_4H_9)_3PO_4$), with a minor amount of triolein ($(C_{17}H_{13}CO_2)_3C_3H_5$) and organic degradation products. The AAW waste was released to the 216-Z-1A Crib on a specific retention basis[4] (see Glossary).

TABLE 2

CHEMICAL COMPOSITION OF TYPICAL 236-Z AND 242-Z PROCESS WASTE (AAW)[3]

HNO_3	0.15M
$Al(NO_3)_3$	0.2M
$AlF(NO_3)_2$	0.3M
$Mg(NO_3)_2$	0.3M
$Ca(NO_3)_2$	0.3M
$NaNO_3$	0.95M

Waste also included CCl_4 and TBP.

From June 1964 to May 1966, the 216-Z-1A Crib received approximately 1×10^6 liters of AAW waste containing an estimated total of 30 kilograms of plutonium (Table 3). The results of a laboratory study completed near the end of this time period indicated that "...disposal of AAW waste to the ground would result in plutonium and americium contamination of all 216-Z-1A sediment materials wetted by the waste liquid."[5] Calculations based on waste discharge rates also indicated that only sediments beneath the northern-most portion of the crib were actually receiving waste liquid.[4] Precautionary measures were subsequently taken to prevent the penetration of actinides to the water table and to prolong the life of the crib. The 216-Z-1A Crib was divided into three sections, designated as "a", "b", and "c" (Figure 4), and the waste distribution point moved to the head of the "b" section.

TABLE 3

ESTIMATED RADIONUCLIDE CONTENT OF LIQUID WASTE RELEASED AT THE HEAD OF THE 216-Z-1A(a) SECTION[2]

	AMOUNT DISCHARGED			TOTAL AMOUNT
RADIONUCLIDE	1964	1965	1966	DISCHARGED
Pu, g	1.43×10^{4}	1.10×10^{4}	4.64×10^{3}	3.0×10^{4}
Beta, Ci	1.01×10^{2}	7.7×10^{1}	3.2×10^{1}	2.1×10^{2}
^{90}Sr, Ci	$<1.0 \times 10^{-1}$			$<1.0 \times 10^{-1}$
^{106}Ru, Ci	4.8×10^{1}	3.7×10^{1}	1.5×10^{1}	1.0×10^{2}
^{137}Cs, Ci	$<1.0 \times 10^{-1}$			$<1.0 \times 10^{-1}$
^{60}Co, Ci	$<1.0 \times 10^{-1}$			$<1.0 \times 10^{-1}$
U, Kg	$<2.0 \times 10^{-2}$	$<2.0 \times 10^{-2}$	$<1.0 \times 10^{-2}$	$<5.0 \times 10^{-2}$
(Volume, Liters)	4.4×10^{5}	9.2×10^{5}	5.4×10^{5}	1.9×10^{6}

Waste was routed to the head of the "b" section by inserting a 30-meter length of 5-centimeter diameter stainless steel pipe inside the clay central distributor pipe. While the stainless steel pipe was being inserted, the waste was diverted to the 216-Z-1 and 216-Z-2 Cribs. From May 1966 to October 1967, approximately 1.9×10^{6} liters of waste containing an estimated total of 16.6 kilograms of plutonium was released from the head of the "b" section. The radionuclide content of this waste is listed in Table 4.

TABLE 4

ESTIMATED RADIONUCLIDE CONTENT OF LIQUID WASTE RELEASED AT THE HEAD OF THE 216-Z-1A(b) SECTION[2]

	AMOUNT DISCHARGED		TOTAL AMOUNT
RADIONUCLIDE	1966	1967	DISCHARGED
Pu, g	1.2×10^{4}	4.6×10^{3}	1.66×10^{4}
Beta, Ci	1.05×10^{2}		1.05×10^{2}
^{90}Sr, Ci	$<1.0 \times 10^{-1}$		$<1.0 \times 10^{-1}$
^{106}Ru, Ci	5.0×10^{1}		5.0×10^{1}
^{137}Cs, Ci	$<1.0 \times 10^{-1}$		$<1.0 \times 10^{-1}$
^{60}Co, Ci	$<1.0 \times 10^{-1}$		$<1.0 \times 10^{-1}$
U, Kg	$<3.0 \times 10^{-2}$	$<2.0 \times 10^{-2}$	$<5.0 \times 10^{-2}$
(Volume, Liters)	9.6×10^{5}	9.4×10^{5}	1.9×10^{6}

In 1967, the point of waste release to the 216-Z-1A Crib was moved to the head of the "c" section by extending the stainless steel pipe an additional 22.5 meters to the south (Figure 4). An estimated total of 10.8 kilograms of plutonium contained in approximately 1.4 X 10^6 liters of liquid waste was discharged to the "c" section from October 1967 to May 1969. The total estimated radionuclide content of the released waste is listed in Table 5.

TABLE 5

ESTIMATED RADIONUCLIDE CONTENT OF LIQUID WASTE RELEASED AT THE HEAD OF THE 216-Z-1A(c) SECTION[2]

	AMOUNT DISCHARGED			TOTAL AMOUNT
RADIONUCLIDE	1966	1967	1968	DISCHARGED
Pu, g	2.4 X 10^3	7.6 X 10^3	8.2 X 10^2	1.08 X 10^4
(Volume, Liters)	2.5 X 10^5	1.0 X 10^6	1.6 X 10^5	1.4 X 10^6

In 1969 the use of the 216-Z-1A Crib was terminated and the waste stream from the Plutonium Reclamation Facility was rerouted to the 216-Z-18 Crib. Upon retirement, the 216-Z-1A Crib had received approximately 6.2 x 10^6 liters of liquid waste containing an estimated total of 57 kilograms of plutonium. This volume of liquid waste is approximately 60 percent of the calculated specific retention volume of the crib. The total radionuclide content of the waste released to the facility is given in Table 6. The cumulative inventory estimates listed in Table 1 and in Tables 3 through 6 are based on the results of routine analysis of the disposed waste liquid. The routine analytical technique did not include a specific determination of americium content. However, based on the estimated efficiency of the americium recovery process, it is calculated that approximately 1 kilogram of ^{241}Am was disposed to the crib.

TABLE 6

ESTIMATED TOTAL RADIONUCLIDE CONTENT OF LIQUID WASTE RELEASED TO THE 216-Z-1A CRIB

RADIONUCLIDE	TOTAL AMOUNT DISCHARGED	DECAY VALUES THROUGH 1977
Pu, g	5.74×10^{4}	5.74×10^{4}
Beta, Ci	3.38×10^{2}	$< 7.5 \times 10^{-1}$
^{90}Sr, Ci	$<3.0 \times 10^{-1}$	$<1.5 \times 10^{-1}$
^{106}Ru, Ci	1.60×10^{2}	3.4×10^{-2}
^{137}Cs, Ci	$<3.0 \times 10^{-1}$	$<1.5 \times 10^{-1}$
^{60}Co, Ci	$<3.0 \times 10^{-1}$	$<3.9 \times 10^{-2}$
U, Kg	$<1.5 \times 10^{-1}$	$<1.5 \times 10^{-1}$
(Volume, Liters)	6.2×10^{6}	6.2×10^{6}

MONITORING WELLS

Prior to the initiation of this study in 1973, 24 wells had been drilled in and around the 216-Z-1A Crib. The primary purpose of these wells was to provide information concerning the movement of the disposed waste. Wells falling into this category have identification numbers less than 100* and are located in Figure 4. Thirteen of these wells (56 through 68) were drilled in 1949 and were located within the interior of the 216-Z-1, 216-Z-2, 216-Z-3, and 216-Z-1A Cribs. Four of these wells have served as access holes for scintillation probe monitoring surveys conducted to detect waste movement.(8)

Prior to reactivation of the 216-Z-1A Crib in 1964, two wells (6 and 7) were drilled to the water table on the east and west side of the facility. These wells were emplaced to serve as both groundwater monitoring wells and as scintillation probe access holes. Five additional scintillation probe access wells (85 through 89) were also located around the perimeter of the 216-Z-1A Crib in 1969.

* All well numbers referred to in the text are prefixed by 299-W18- (6, 7).

Between activation of the 216-Z-1A Crib in 1949 and the initiation of this study in 1973, drilling within the interior of the facility was limited to the emplacement of six shallow wells in the abandoned "a" section. These wells were drilled in 1967 to determine if the suspected buildup of waste liquid near the head of the crib could be confirmed. The data derived from the six wells (76 through 81) indicated that the 1964 decision to reposition the waste outlet point was justifiable.(4)

EMPLACEMENT OF CHARACTERIZATION WELLS

The data discussed in this report were derived primarily from the analysis of sediment samples collected from 16 wells drilled since the initiation of the study in 1973. The location of these wells was based on the overall study objective -- to determine the present configuration of the waste plume beneath the 216-Z-1A Crib. Wells drilled for this purpose have identification numbers greater than 100 and are located in Figure 4. To prevent the release of actinides to the uncontrolled environment, these wells were emplaced using either totally or partially contained drilling conditions.

LOCATION OF WELL SITES

The primary objective of the characterization effort was to emplace wells which could be used to define the vertical and lateral extent of contamination beneath the 216-Z-1A Crib. Based upon a review of crib construction and disposal history, it was initially determined that a minimum of 13 wells would be required to establish the boundary of the waste plume. Four of these wells were located along the central distributor pipe, one at the head of the "a" (well 149), "b" (well 175*), and "c" (well 159) sections, and one at the end of the central distributor pipe (well 150) (Figure 4). The primary purpose of these center wells was to obtain information at locations where maximum waste discharge to the crib was expected. The remaining nine wells (well 158, wells 163 through 169, and well 172), were located around the perimeter of the crib. The primary purpose of these wells was to determine the lateral extent of contamination.

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*Well 170 was to be emplaced at the head of the "b" section to an approximate depth of 38 meters. At a depth of 9 meters, an obstruction was encountered which the equipment could not penetrate. Further drilling in well 170 was stopped and a second well, 175, was located 1.5 meters south of well 170 as a substitution.

Following the drilling of each well, the accumulated actinide distribution data was reviewed. Such a successive review was conducted to determine if the planned placement of the remaining wells should be modified. As a result of this review, three additional wells were emplaced to provide more specific information concerning the lateral spread of waste liquid. The locations of these wells, numbers 171, 173, and 174, are shown in Figure 4.

DRILLING AND CONTAINMENT METHODS

A major concern of the 216-Z-1A Crib study was to obtain representative sediment samples without releasing actinide contamination to the uncontrolled environment. In order to accomplish this objective, three drilling and containment methods were designed and employed during the study. These drilling methods are discussed below.

Totally Contained Cable Tool Drilling

The first two wells drilled for the purpose of actinide distribution determinations, were wells 149 and 150. These wells were located, respectively, at the head and at the end of the 216-Z-1A Crib central distributor pipe, as shown in Figure 4. Emplacement of both of the wells was carried out using a modified cable tool drilling rig, a method that does not require the introduction of any lubricating medium into a well during drilling. Because of the relatively "high" level of actinide contamination anticipated during drilling operations, the tools of the drilling rig were enclosed by a containment structure consisting of three barriers. "Totally contained" drilling (see Glossary) was carried out within a sealed, plastic primary enclosure (Figure 7) surrounded, as a precautionary measure, by a larger plastic secondary enclosure (Figure 8). The tops of the primary and secondary enclosures were equipped with accordion bellows which accommodated the rise and fall of the driving weights during drilling operations. A slight negative pressure was maintained independently on both the primary and secondary enclosures utilizing absolute filter blower assemblies. Sampling personnel were positioned in the secondary enclosure and sample handling was carried

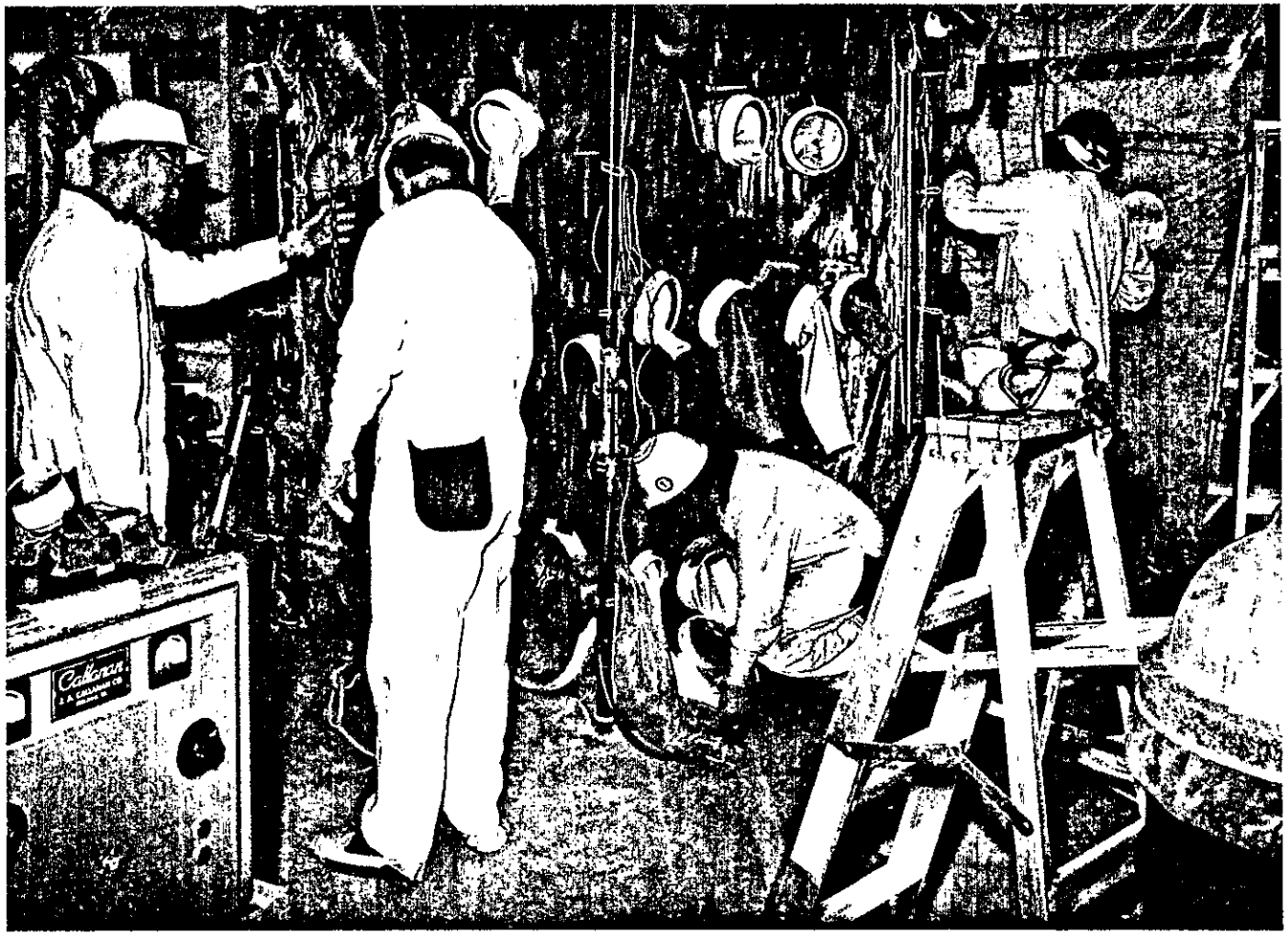

FIGURE 7 PRIMARY ENCLOSURE SURROUNDING WELL 150

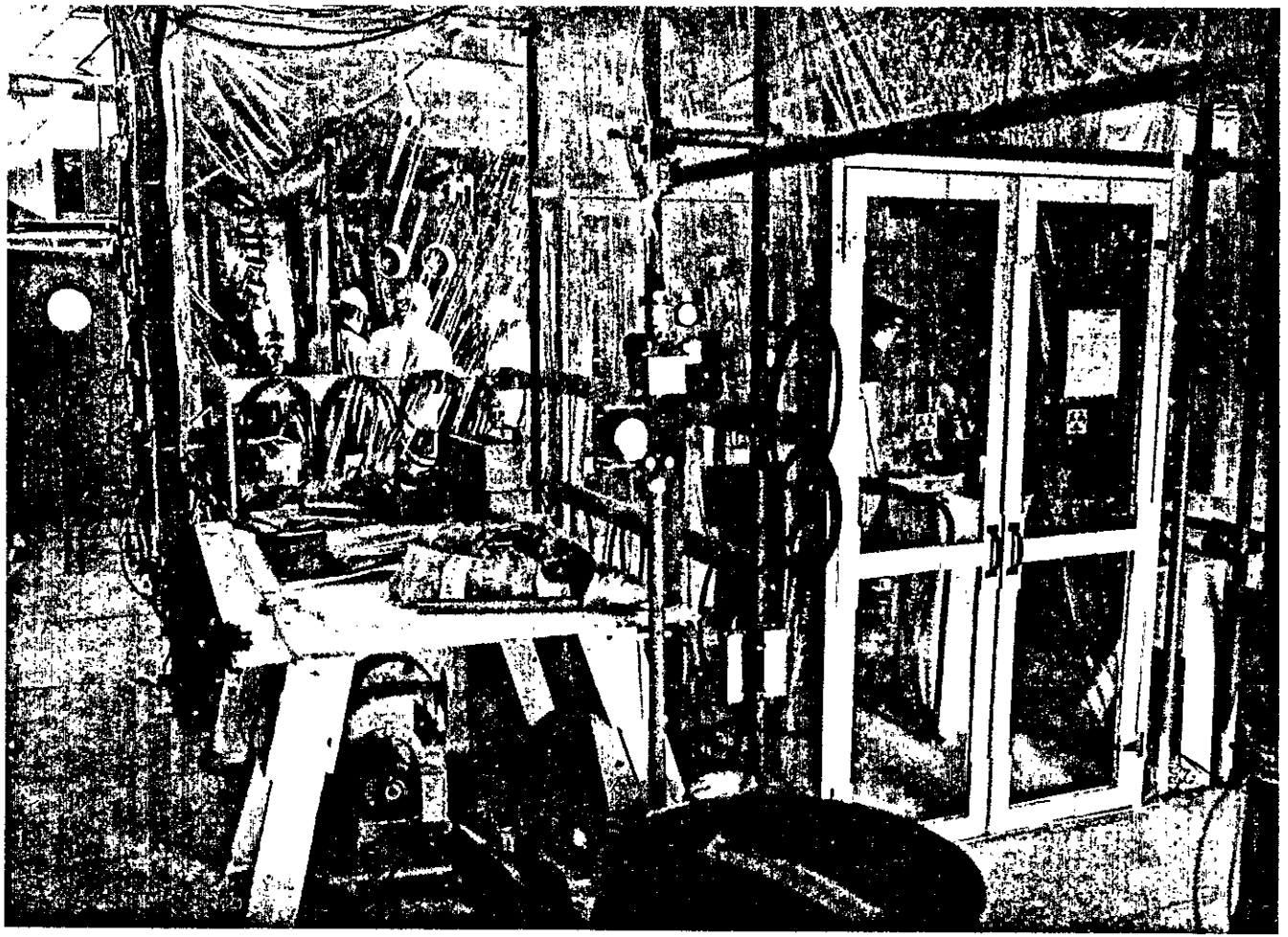

FIGURE 8 SECONDARY ENCLOSURE

out by working through glove ports in the primary. A tertiary barrier (Figure 9), constructed of plywood and canvas, surrounded the two plastic barriers to provide protection from the weather.

Emplacement of well 149 was carried out using a drive barrel sampler. This sampler, essentially consisting of a hollow tube composed of hardened steel, is shown in Figure 10. During drilling, the tube was driven approximately 1 meter in depth, and subsequently raised to the surface. Sediments within approximately 15 centimeters of the bottom of the sampler, were emptied into a plastic-lined 1-liter sample container by tapping the side of the sampler with a hammer. Afterwards, the sample container was "sealed-out" (see Glossary) of the primary enclosure, surveyed with portable radiation survey instruments, geologically characterized, and further packaged to prevent the release of contamination during transport and storage. In order to deepen the well, casing (see Glossary) was subsequently driven approximately 1 meter before sampling was repeated. The well was progressively deepened by alternating the driving of sampler and casing. Throughout the entire operation, the depths of the casing and sample barrel were recorded before and after each successive drive in order to calculate what portion of the sample was the result of sidewall sloughing.

Sampling of the first 10 meters of well 150 was carried out using a split-tube core barrel sampler. This sampler consists of a drive head, drive shoe, sample retainer ring, and segmented sample liners. A picture of a disassembled sampler is included in Figure 10. During drilling, the split-tube sampler was driven approximately 1 meter and subsequently raised to the surface. At the well head, the sampler was dismantled (within the primary enclosure), and sediments contained in the shoe and in each 12-centimeter long liner were segmented and individually packaged. Samples were then "sealed out" from the primary enclosure, surveyed, and packaged for transport and storage. Following sampling, the casing was driven and further sampling and drilling was carried out in the manner described in the previous paragraph. Visual inspection of the samples revealed that comparable results were obtained using either the drive

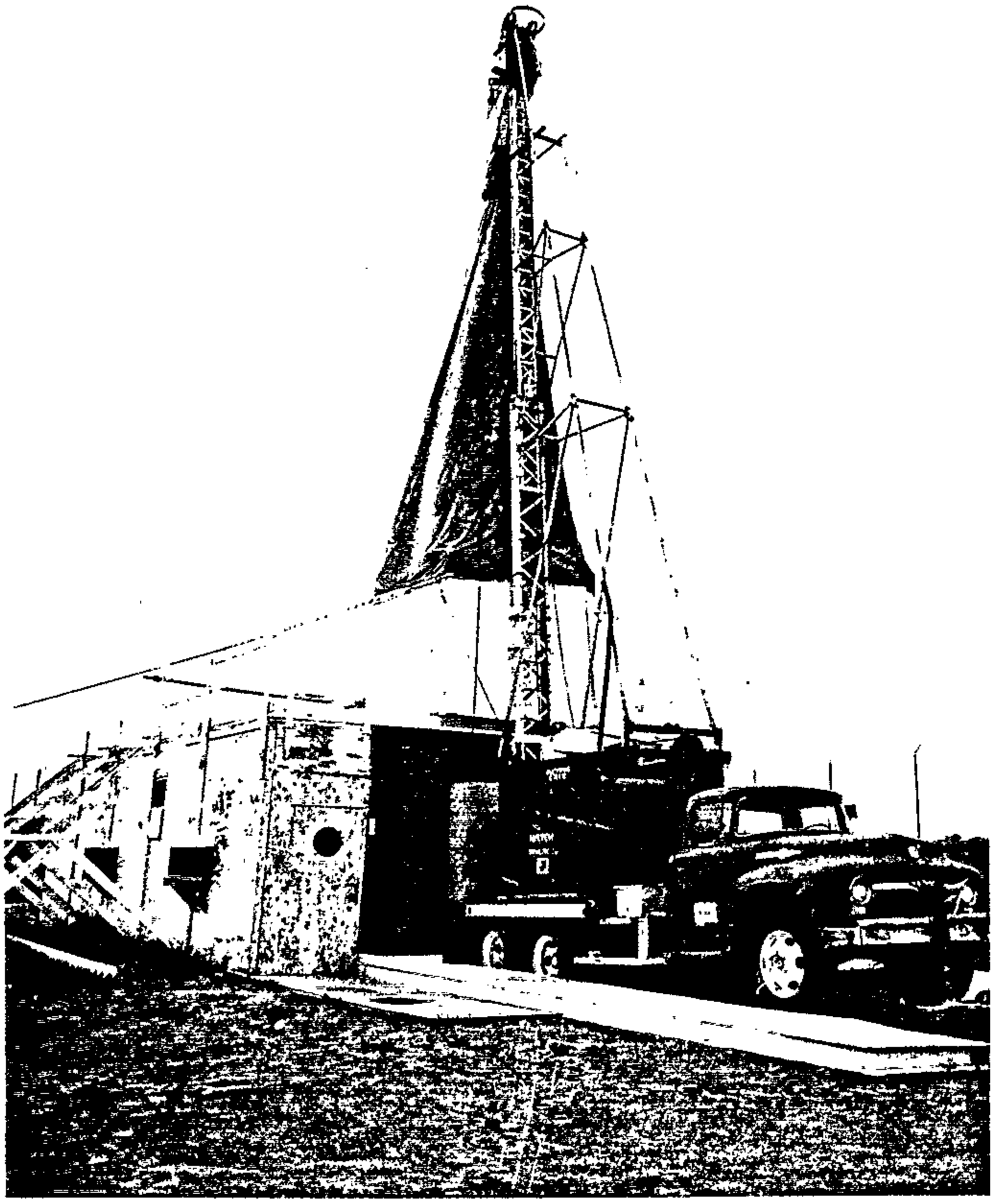

FIGURE 9 OUTSIDE VIEW OF CONTAINMENT STRUCTURE WITH CABLE TOOL DRILLING RIG

FIGURE 10 DISASSEMBLED SPLIT-TUBE CORE BARREL SAMPLER (LEFT) AND DRIVE BARREL SAMPLER (RIGHT)

barrel or split tube sampler. Consequently, the simpler, and less time-consuming drive barrel method was used to sample sediments in the lower portion of well 150 (from 10 meters to 30 meters in depth).

Dual-Wall Core Barrel Drilling

Drilling of well 149 and 150 revealed that a more rapid, and more economical way of carrying out "totally contained" sampling was required. To meet this need, the "dual-wall" core barrel method was developed, and used to sample the upper portions of wells 159, 170, and 175. This method employed a conventional cable tool rig to drive a 10-meter long sampler consisting of an outer and an inner barrel (Figure 11). At the completion of a drive, the inner barrel was withdrawn into a plastic containment bag. The outer barrel remained in the hole as casing, as shown in Figure 11. After withdrawal, the inner barrel was transported to a greenhouse (see Glossary) and cut into 50-centimeter long segments for sampling purposes.

Selectively Contained Cable Tool Drilling

Experience gained during the drilling of wells 149 and 150 allowed the formulation and testing of a third drilling technique -- "selective containment" (see Glossary). This technique was subsequently used to drill the perimeter wells 158, 163 through 169, and 172 and to deepen center wells 159 and 175. Drilling was carried out using a cable tool rig equipped with a drive barrel sampler. The technique was implemented at each well site by constructing a temporary "greenhouse" (see Glossary) around the well head. Throughout drilling, the sampling crew and driller wore protective clothing and were equipped with protective respirator equipment. Upon completion of a sample drive, the cable used to hoist the sampler and the sampler were continuously surveyed for contamination and cleaned if activity was detected. Following sampler surveying, the sediments contained in the lower 25 centimeters of the sample barrel were emptied into a plastic sample bag for the purpose of actinide analysis. Sediments remaining in the upper portion of the sampler were released to a second plastic bag by tapping the side of the sampler with a hammer.

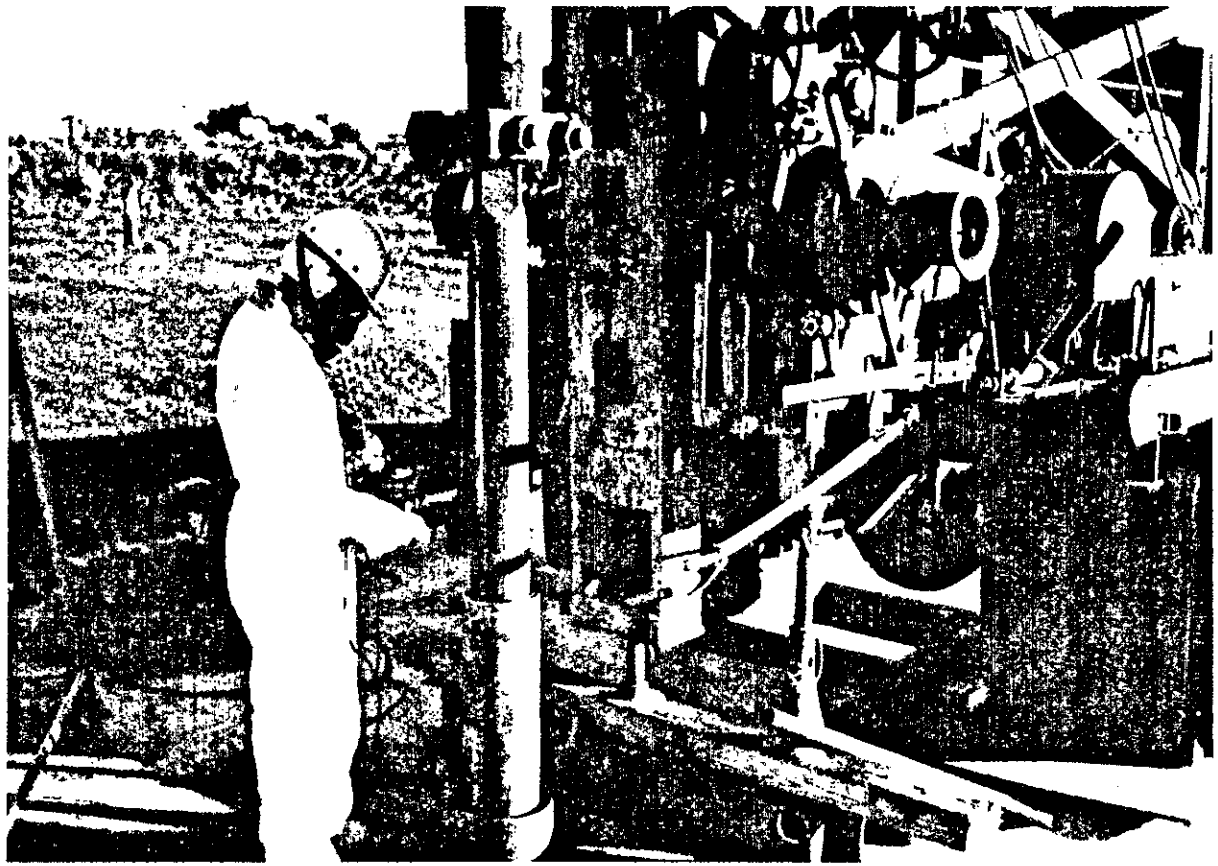

FIGURE 11 RADIATION MONITOR SURVEYING INNER BARREL OF THE DUAL-WALL CORE BARREL

Subsequently, the sediments in each bag were spread flat and portable radiation survey instruments were used to monitor the contents. Such precautions were taken to assure that contaminated sediments possibly contained within the upper portion of the sampler did not go undetected.

SAMPLING PROCEDURES

During drilling, samples were collected throughout the sediment column for purposes of geologic and actinide analysis. In sediment horizons where contamination was undetected with portable radiation survey instruments, samples were collected approximately every 1.5 meters or where there was a change in sediment type. In sediment horizons where contamination was detected with portable radiation survey instruments, samples were collected approximately every 0.3 meters. During well emplacement, drill logs of both sediment type and portable radiation survey instrument readings were maintained. Drill logs for the 16 characterization wells emplaced during the study are included in Appendix B.

Throughout drilling, the potential for sampling error due to "cross-contamination" (see Glossary) was recognized. An effort was made to deal with this factor within the constraints imposed by safety requirements. At the well site, samplers were continually monitored and cleaned if "smearable" contamination was detected. However, as a precautionary measure, recycled sampling barrels were labeled and used only where a specific level of contamination was expected to be encountered. In addition, the casing in most wells was "telescoped" (see Glossary) where discontinuous, but successively deeper areas of contamination were encountered during drilling. "Telescoping" was implemented to prevent the dust, coating the inside of the casing in the upper portion of the well, from cross-contaminating sediments at depth. Actinide analytical results, discussed later in the text, indicated that efforts to prevent cross-contamination were effective.

ANALYTICAL PROCEDURES

Selected samples obtained from wells drilled through and in the vicinity of the 216-Z-1A Crib were analyzed by granulometric and by actinide analytical techniques. Granulometric data, supplemented with drill log information, were used to interpret the geology beneath the crib. Actinide analytical data, supplemented with available scintillation survey records,[8] and drill log data were used to interpret the pattern of plutonium and americium contamination beneath the facility. Analytical results are graphically summarized in concentration profiles included in Appendix B and in the activity isopleth cross sections included in Appendix D.

GRANULOMETRIC ANALYSIS

The 216-Z-1A Crib is underlain by approximately 150 meters of unconsolidated to partially consolidated sediments. Formulation of a stratigraphy for these sediments was partially based on data obtained using a size classification procedure termed granulometric analysis. A brief discussion of the sample selection and analytical methods used to conduct granulometric analysis follows.

Sample Selection

The granulometric analytical procedure was carried out with uncontaminated sediment samples from eight wells drilled through and in the vicinity of the 216-Z-1A Crib. Three of these wells were drilled prior to the initial release of waste liquid. The remaining five wells were drilled after crib activation but in an area beyond the boundary of the waste plume. All eight wells were emplaced using a cable tool drilling rig equipped with a drive barrel sampler. The sampling interval was approximately every 1.5 meters.

Sieving Procedure

Granulometric data were obtained for samples using a standard sieving procedure. Samples were sieved into nine size fractions using eight screens with mesh sizes listed in Figure 12. To determine these size

PARTICLE DESIGNATION			PARTICLE DIAMETER (MM)	SIEVE SIZES (MM)
GRAVEL	BOULDER		>256	
	COBBLE	LARGE	256-128	
		SMALL	128-64	
	PEBBLE	VERY COARSE	64-32	
		COARSE	32-16	
		MEDIUM	16-8	
		FINE	8-4	>4
		VERY FINE	4-2	2
	SAND	VERY COARSE	2-1	1
		COARSE	1-0.5	0.5
		MEDIUM	0.5-0.25	0.25
		FINE	0.25-0.125	0.125
		VERY FINE	0.125-0.0625	0.0625
	SILT & CLAY	COARSE SILT	0.0625-0.037	0.037
		LESS THAN COARSE SILT	<0.037	<0.037

FIGURE 12. GRAIN SIZE NOMENCLATURE (MODIFIED AFTER C. K. WENTWORTH[9])

fractions, samples were dried, split into approximately 150-gram subsamples, weighed, and shaken through a nest of sieves. The disaggregate retained by each sieve was then weighed and recorded. Depending upon the weight percent of the various size fractions, the sediment samples were categorized into one of 19 sediment classes (Figure 13) using a computer program termed ROC.[10] In addition to granulometric data, calcium carbonate content was determined for all sieve samples using a carbon dioxide displacement method.

Uncontaminated sediment samples collected from wells are stored in jars with a mouth diameter of approximately 7 centimeters. Consequently, sediments larger than small cobbles (Figure 12) were not included in the sample fractions submitted for granulometric analysis. However, the presence of cobble-sized or larger fragments in wells was discernable by an examination of the drill logs. Geologic cross sections based on granulometric and drill log data are included in Appendix C.

PLUTONIUM AND AMERICIUM ANALYSIS

Approximately 400 sediment samples from beneath the 216-Z-1A Crib were selected for plutonium and americium determinations. Samples were quantitatively analyzed using one or more of the following detector systems: 1) lithium drifted germanium Ge(Li); 2) intrinsic germanium (IG); 3) lithium drifted silicon Si(Li); and 4) alpha energy. These methods were selected on the basis of the following criteria: 1) estimated sample activity; 2) required turn-around-time; and 3) the need for inter-laboratory cross-checks. The procedures by which samples were selected and analyzed are discussed briefly in the remainder of this section.

Sample Selection

During and after well emplacement, sediment samples were selected for quantitative actinide analysis. Due to the analytical methods employed, samples collected from sediment horizons comprised predominantly of cobble-sized or larger fragments were not submitted for analysis. With this exception, samples were collected at 0.3 to 2-meter intervals from

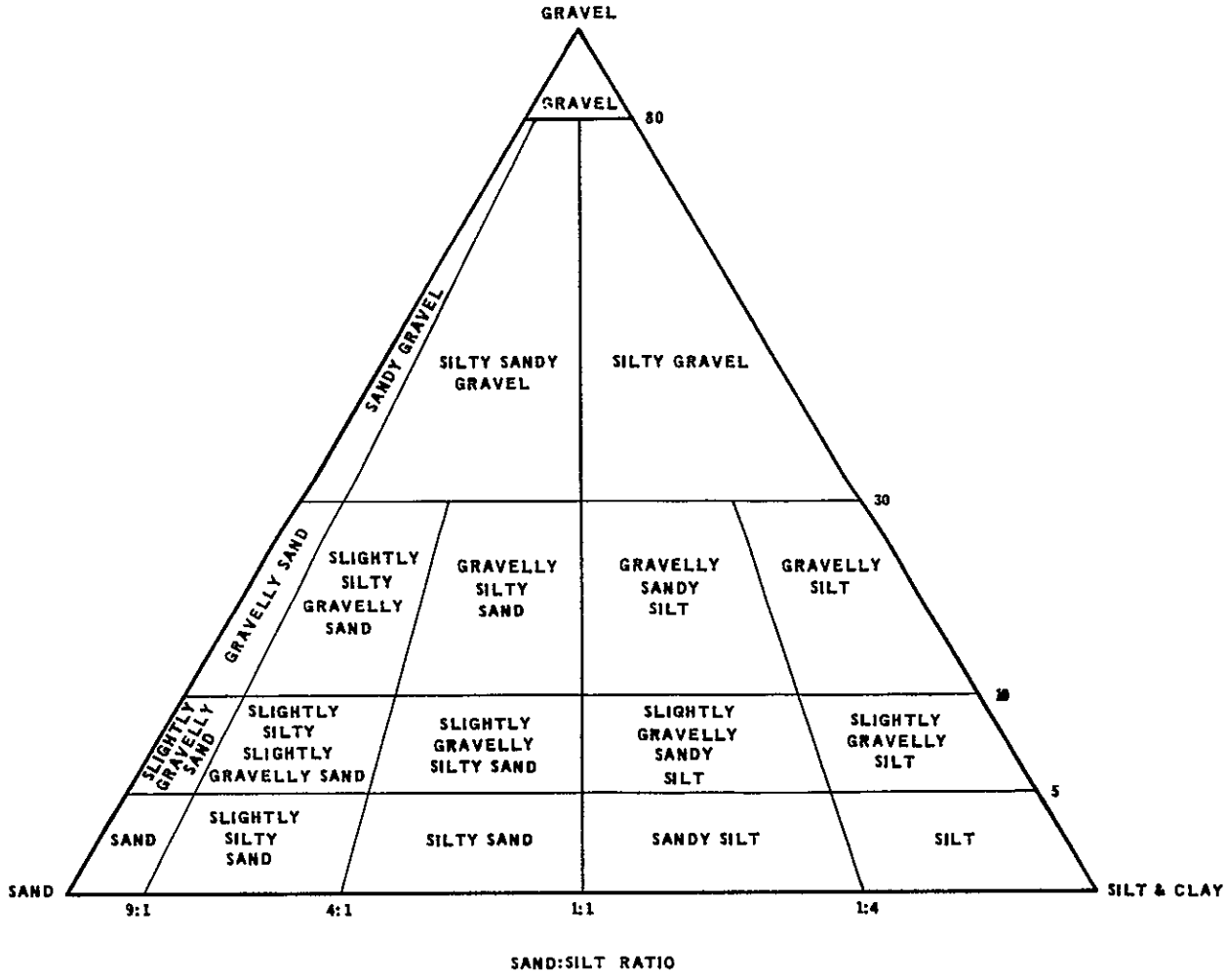

FIGURE 13 SEDIMENT CLASSIFICATION (MODIFIED AFTER R. L. FOLK[11])

sediment horizons where activity was detected using a "poppy", "PAM", and "GM",[19] standard Hanford portable radiation survey instruments. Samples were also selected at approximately 1 to 5 meter intervals from sediment horizons where activity was not detected with portable radiation survey instruments. These samples were collected to determine if activity less than approximately 2.3×10^{-1} nCi (at the surface of a 100-square centimeter detector) was present.

Results of other studies indicate that the distribution of actinides in soil can be highly variable.[13, 14] To reduce sampling error due to sample inhomogeneity, sediments were mixed in their respective storage containers prior to selecting aliquots for actinide analysis. However, in order to determine the statistical variability of actinide concentrations in 216-Z-1A samples, replicate analyses of all samples would have to be obtained.

Analyses of samples submitted from wells drilled during this study are listed in Appendix A. Also listed in Appendix A are quantitative analyses of selected samples from wells 85 through 89, drilled after crib retirement but prior to 1973. Information obtained from these wells was also used to define the waste envelope.

Sample Analysis

Ge(Li) Detector System All samples obtained during drilling of the first well, 149, were sent to an analytical laboratory within the 200 West Chemical Separations Area operated by Atlantic Richfield Hanford Company (predecessor to Rockwell). Samples were counted using a Ge(Li) detector system[15] capable of analyzing contaminated material containing plutonium activity greater than 50 nCi/g and americium activity greater than 0.3 nCi/g. The ^{239}Pu gamma at 414 KeV, the ^{240}Pu gamma at 104 KeV, and the ^{241}Am gamma at 59.6 KeV were counted. Calibration standards were prepared using sediments containing known concentrations of plutonium and americium. Sediments were counted in either 25-milliliter or 500-milliliter plastic containers dependent upon the estimated activity level of the sample.

Intrinsic Germanium (IG) Detector System The bulk of the samples were analyzed by Pacific Northwest Laboratory (PNL) using an IG detector

system.[16] The ^{239}Pu X-ray at 17.0 KeV, the ^{240}Pu X-ray at 17.3 KeV, and the ^{241}Am gamma at 59.6 KeV were counted using calibration standards prepared by PNL. Plutonium was reported as total $^{239, 240}Pu$. The limit of detection for plutonium using this system is estimated at 10^{-2} nCi/g and the limit of detection for americium is estimated at 10^{-4} nCi/g. Samples were submitted for analysis as 100-gram aliquots contained in plastic vials with a polycarbonate window.

Si(Li) Detector System Intelcom Radiation Technology (IRT) Laboratory analyzed selected samples using a Si(Li) detector.[17] This unit counted peaks at the same energy levels as the IG system used by PNL. The estimated detection limit for plutonium ($^{239, 240}Pu$) using the Si(Li) system is 0.6 nCi/g and the estimated detection limit for americium is 10^{-2} nCi/g. Calibration standards were provided by Rockwell. Samples were analyzed as 100-gram aliquots contained in plastic vials with a polycarbonate window.

Alpha Energy Detector System Selected samples were analyzed by LFE Laboratory using a surface barrier alpha energy detection method.[18] In this method, 10 grams of sediments were chemically digested, isotopic tracers added, and the plutonium and americium separated, electroplated, and counted. The estimated detection limit using this technique is 2×10^{-5} nCi/g for both plutonium ($^{239, 240}Pu$) and americium.

Analytical Results and Statistical Analysis

The results of all analyses of 216-Z-1A sediment samples are reported in Appendix A. Plutonium and americium activities and the counting standard deviations are given. The laboratory that performed each analysis is also reported. The confidence in the analytical values reported by the quantitative methods is estimated in the counting standard deviation, or sigma (σ). Sigma is assumed to approximate the true standard deviation (s.d.) and is subsequently used as such. Sigma is defined as:

$$\sigma = \left(\frac{\text{Total Counts + Bkg Counts}}{\text{Counting Time}}\right)^{1/2} \times (1/\text{Sample Weight}) \times (D/C)$$

where Total Counts are the gross counts measured by the detector for the energy peak being counted. Background (Bkg) Counts are the calculated background counts in the energy range counted and D/C is the efficiency factor for the instrument.

The analytical results for plutonium and americium reported in Appendix A are plotted versus depth in Appendix B along with the lithologic logs. Where multiple analyses for individual samples at the same depth are reported by more than one laboratory, the results from the laboratory with the lowest limit of detection are plotted.

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GEOLOGICAL SETTING AND INTERPRETATION

The Hanford site lies within the Pasco Basin, a broad structural and topographic depression located within the Columbia Plateau physiographic province shown in Figure 14. The site is underlain by three major stratigraphic formations. They are, in descending order: (1) unconsolidated sand, silt, and gravel of the "Hanford Formation"; (2) semiconsolidated clay, silt, sand, and gravel of the Ringold Formation; and (3) Yakima Basalt flows of the Columbia River Group. The regional geologic character and geologic history of these three formations have been discussed in previous publications,[1,19] and only the character of the geology specific to the 216-Z-1A Crib will be discussed within this document.

The geology in the vicinity of the 216-Z-1A Crib has been interpreted from an analysis of 47 wells drilled directly through the site or within a 1 kilometer radius. The wells used as data points are specifically located in Figures 4 and 15 and will be identified by the numbers designated in these figures throughout the remainder of the text. Because the liquid waste routed to the 216-Z-1A Crib was released to the underlying "Hanford Formation", this formation will be discussed first and in most detail.

The sediments of the "Hanford Formation" (local formation name) were deposited by catastrophic floods which resulted from the periodic breakup of glacial dams located near the present Canadian border. Catastrophic flooding is estimated to have last occurred between 10,000 and 20,000 years before present, but may have occurred several times before this period.

The character of the "Hanford Formation" beneath the 216-Z-1A Crib was determined by an examination of the sediment samples from 44 wells plotted in Figure 4. Sediments from all of these wells were logged in the field and qualitatively classified into the size categories outlined in Figure 12. Granulometric and $CaCO_3$ analyses were also performed on samples from 8 of these wells, and the sediments subsequently categorized

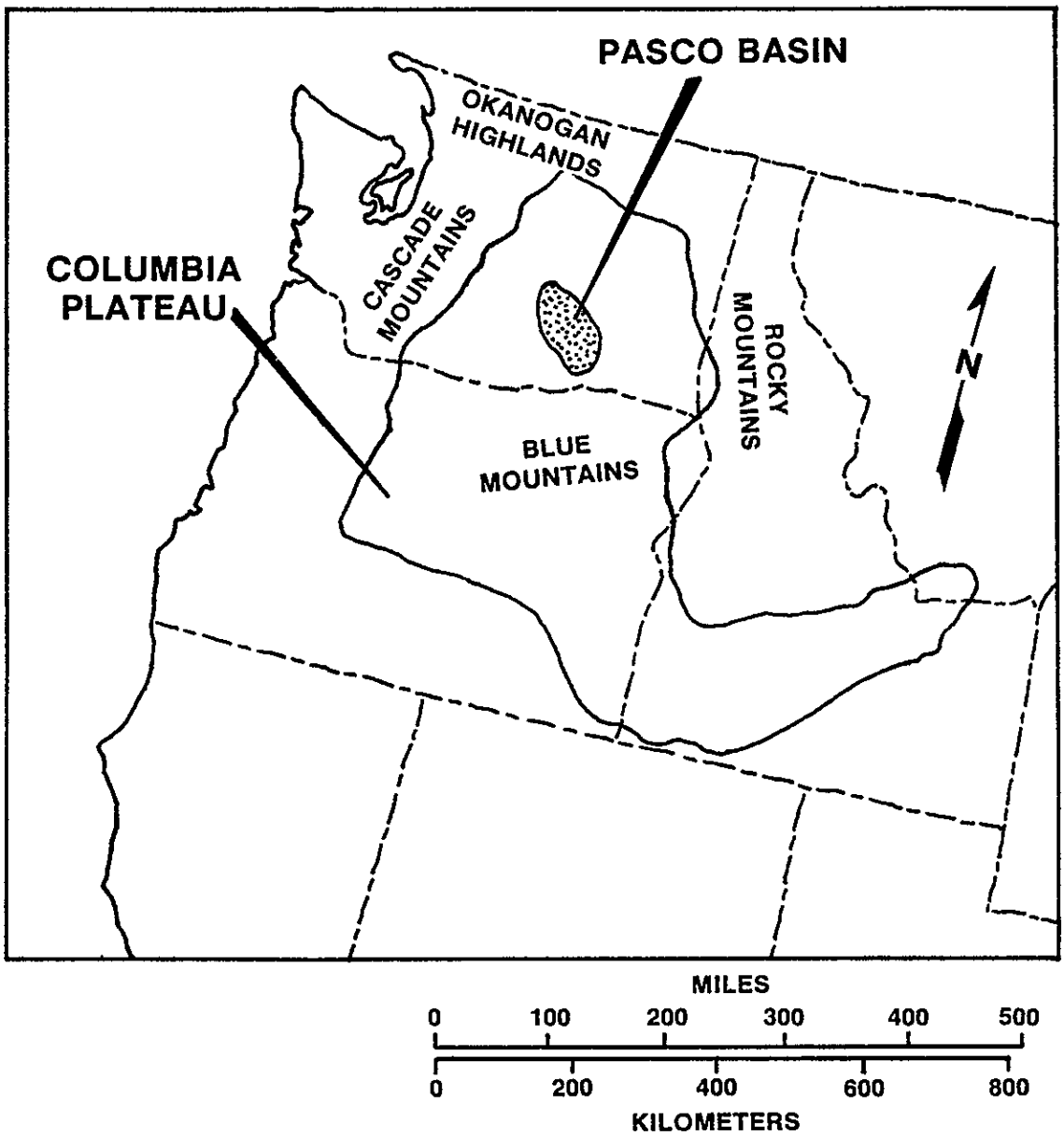

FIGURE 14 COLUMBIA PLATEAU PHYSIOGRAPHIC PROVINCE

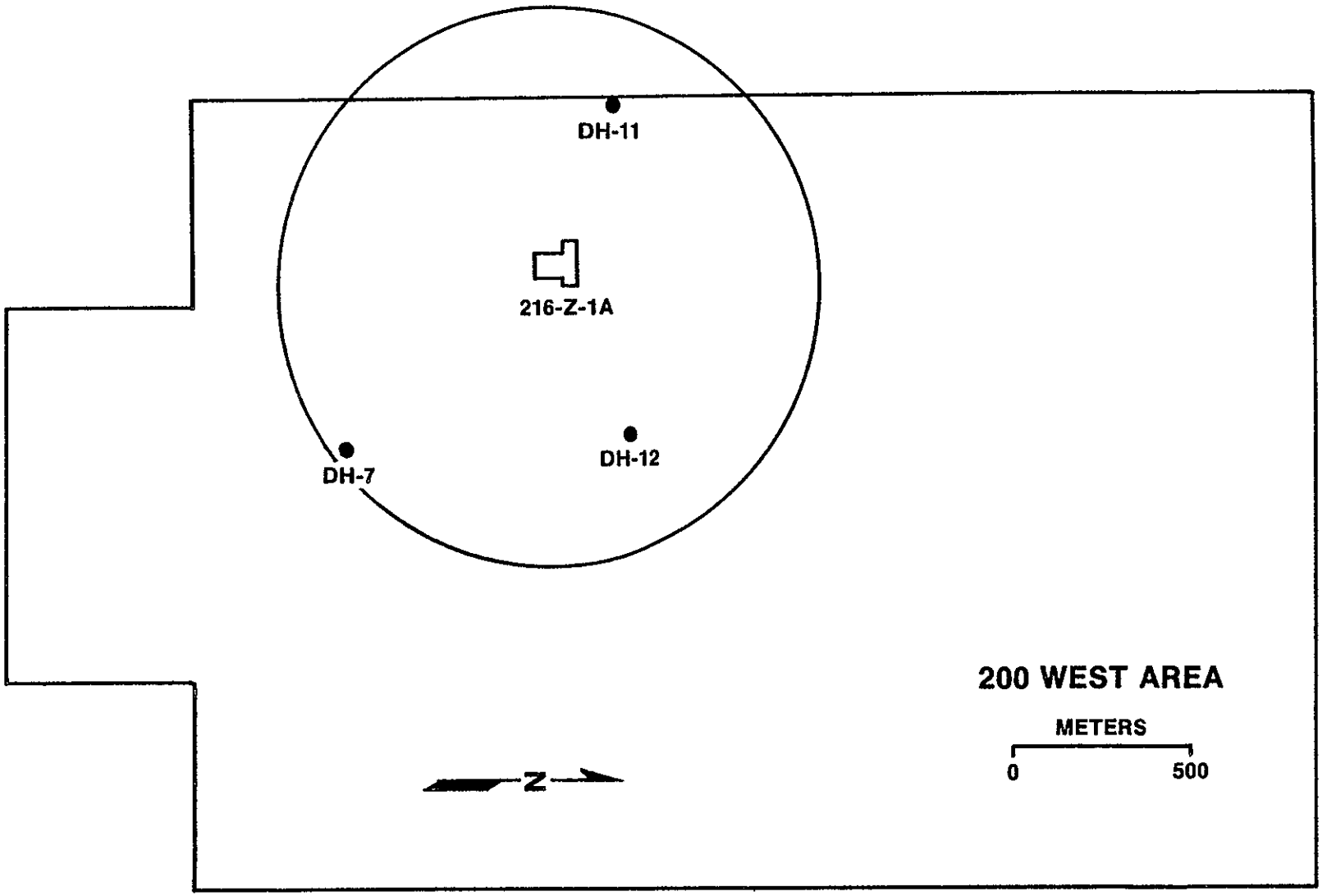

FIGURE 15 LOCATIONS OF CORE WELLS TO BASALT

into one of the 19 grain size classes outlined in Figure 13. An examination and extrapolation of both field data and granulometric data from these wells indicated that the "Hanford Formation" beneath the 216-Z-1A Crib is divisible into five basic units. The extent and configuration of these units are represented in the east-west and north-south cross sections included as Plates 27 through 32, Appendix C. A discussion of the character of each of the five units follows.

The uppermost "Hanford Formation" unit is composed predominantly of fine to very fine sand. This unit extends from the surface to approximately 5 meters in depth. Granulometric and $CaCO_3$ analyses of this unit are listed in Table 7. The sediments of this unit were excavated during tile field construction and replaced with backfill comprised of a mixture of sand, gravel, and cobbles (see Crib History section). Consequently, the fine to very fine sand unit is preserved only along the margin of the crib.

The fine sand unit is underlain by a sandy coarse to fine pebble unit. This unit averages 10 to 15 meters thick and is generally flat lying, poorly sorted, and crudely bedded. Granulometric and $CaCO_3$ values for this unit are given in Table 7. The upper portion of this unit contains a coarse sand lens shown in cross sections A-A', B-B', and C-C', Plates 27, 28, and 29. The lower 2 to 3 meters of the unit contains a greater abundance of pebble and cobble lenses.

The sandy coarse to fine pebble unit is underlain by a well-bedded and generally flat lying medium to fine sand unit. Granulometric and $CaCO_3$ analyses of this unit are given in Table 7. This unit characteristically contains abundant discontinuous pebble and silt stringers. However, only those pebble and silt stringers greater than 15 to 20 centimeters in thickness are recorded on the geologic cross sections included in Appendix C. The medium to fine sand unit ranges from 10 to 20 meters thick and is the thickest definable unit beneath the crib.

Underlying the medium to fine sand unit is a pebbly, very coarse to medium sand unit which is generally well sorted. This unit typically contains crudely bedded coarse sand layers interbedded with granular "pea-sized" gravel layers. Granulometric and $CaCO_3$ analyses of this

TABLE 7

TYPICAL GRAIN SIZE AND CALCIUM CARBONATE
VALUES FOR HANFORD FORMATION SEDIMENTS BENEATH THE 216-Z-1A CRIB

SEDIMENTARY UNIT	GRAIN-SIZE PERCENTAGE							
		%Sand						
	%Pebble &Cobbles	Very Coarse	Coarse	Medium	Fine	Very Fine	%Silt &Clay	$\%CaCO_3$
1. FINE TO VERY FINE SAND	5	8	9	13	23	29	13	0.7
2. SANDY COARSE TO FINE PEBBLE	22	25	15	12	9	6	11	0.5
3. MEDIUM TO FINE SAND	2	5	8	18	25	20	22	2.0
4. PEBBLY VERY COARSE TO MEDIUM SAND	20	23	19	12	6	5	15	1.0
5. SILTY MEDIUM TO FINE SAND	0.5	4	7	12	17	24.5	35	2.0

unit are listed in Table 7. The pebbly, very coarse to medium sand layer ranges in thickness from 11.5 meters in well 172 to undetectable in well 175 as shown in Plate 31. Well data indicate that the contact between this unit and the underlying unit slopes approximately 5 degrees to the southwest.

The lowest definable "Hanford Formation" unit beneath the 216-Z-1A Crib is a massively bedded silty medium to fine sand unit. The unit averages 25 percent silt but contains abundant "stringers" with an average silt content of greater than 75 percent. Granulometric and $CaCO_3$ analyses representative of the sandy silt unit are listed in Table 7. The thickness of the unit averages 3 meters and generally increases toward the east.

The glaciofluvial sediments of the "Hanford Formation" rest upon an eolian silt derived from subaerial erosion of the underlying Ringold Formation. Caliche horizons which are present within the eolian silt and the top of the Ringold Formation suggest deposition in an arid environment. At least 33 of the wells drilled within the vicinity of the 216-Z-1A Crib penetrate into or through the eolian silt unit. Samples from these wells show that the eolian silt is generally compact, buff-colored, and massive. A caliche content of greater than 7 percent is common. The thickness of the eolian silt beneath the 216-Z-1A Crib averages 4 meters.

The eolian silt unit overlies the Ringold Formation. This formation was deposited in the Pasco Basin between 3 and 8 million years before present. Ringold sediments were derived from the drainage basins of the ancestral Columbia, Yakima, and Snake Rivers. Within the region of the Hanford site, the Ringold Formation is divisible into three major facies. They are, in descending order: 1) fine sand and silt of the "upper Ringold"; 2) occasionally cemented sand and gravel of the "middle Ringold"; and 3) clay and silt of the "lower Ringold".

The character of the Ringold Formation within the vicinity of the 216-Z-1A Crib was determined by an examination of samples from three core

wells located in Figure 15. Although the "middle" and "lower Ringold" facies are represented beneath the crib, the "upper Ringold" facies is missing due to a lack of deposition and/or to erosion. The thickness and configuration of the "middle" and "lower Ringold" facies beneath the 216-Z-1A Crib is shown on Plates 27 through 32. The water table beneath the crib lies within the sediments of the "middle Ringold" at an approximate elevation of 147 meters above mean sea level (55 meters beneath ground surface).

The Ringold sediments rest on basalt flows of the Columbia River Group which were extruded between 8 and 20 million years before present. Core holes drilled into the volcanics beneath the Hanford site indicate that the accumulation of Columbia River Basalt flows is at least 1500 meters thick. The top of the basalt beneath the 216-Z-1A Crib, determined from DH-7, 11, and 12 well data (Figure 15), is approximately 38 meters above sea level (or 163 meters beneath the ground surface).

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INTERPRETATION OF ACTINIDE DISTRIBUTION

Consideration of the actinide distribution beneath the 216-Z-1A Crib is based on: 1) laboratory analyses of samples listed in Appendix A; 2) drill log data included in Appendix B; and 3) scintillation probe data.[8] These data were used to construct concentration profiles (Appendix B), three sets of east-west isopleth cross sections (A-A', B-B', and C-C', Plates 33-41), and three sets of north-south isopleth cross sections (D-D', E-E', and F-F', Plates 42-50). The isopleth cross sections illustrate an interpretation of plutonium, americium, and total activity (see Glossary) in sediments beneath the crib. Details of the contouring procedure are outlined in Appendix D.

The subsequent discussion of the actinide distribution beneath the 216-Z-1A Crib is divided into three parts: 1) a discussion of the activity found in center wells, i.e. wells drilled along the central distributor pipe; 2) a discussion of activity penetrated by the perimeter wells; and 3) a discussion of possible mechanisms responsible for the observed pattern of distribution.

CENTER WELL DATA

A discussion of the actinide distribution in sediments beneath the central distributor pipe is centered around north-south isopleth cross section E-E' (Plate 1) presented in Plates 45-47. This cross section incorporates data from all four center wells (149, 150, 159, and 175, Appendix A) and from three perimeter wells (164, 171, and 172). The following conclusions concerning actinide distribution beneath the center of the 216-Z-1A Crib can be drawn from an examination of the concentration profiles for these wells (Appendix B) and isopleth cross section E-E' (Appendix D):

(1) The highest concentration of $^{239,240}Pu$ (approximately 4×10^4 nCi/g) and ^{241}Am (approximately 2.5×10^3 nCi) is found in sediments located beneath the central distributor pipe.
(2) With the exception of isolated silt lenses, plutonium concentrations greater than 10^3 nCi/g were not found below a depth of approximately 2 meters beneath the crib; plutonium concentrations greater than 10^2 nCi/g

were not found below a depth of 15 meters. Americium concentrations greater than 10^{1} nCi/g were not found below a depth of approximately 15 meters beneath the crib.

(3) Total activity greater than 10^{2} nCi/g predominantly occurs in sediments located above 15 meters in depth; the bulk of the actinide activity is located within this portion of the sediment column.

(4) In general, total activity decreases with depth beneath the central distributor pipe. Increases in plutonium and americium concentration at depth are generally associated with an increase in the silt content of sediments or with boundaries between major sedimentary units.

(5) Contamination in the 4 center wells (149, 150, 159, and 175) is nearly continuous to the depth of the 10^{-2} nCi/g isopleth for total activity. Samples analyzed by LFE from the sandy silt layer below this isopleth have a total activity of less than 10^{-5} nCi/g (approximate limit of detection). Samples analyzed by PNL have a total activity less than 10^{-2} nCi/g (approximate limit of detection).

(6) The approximate vertical extent of the waste plume (outlined by the 10^{-2} nCi/g isopleth for total activity) is deeper beneath the southern and northern portion of the crib than beneath the center portion. Contamination extends to a depth of approximately 30 meters beneath the "a" and "c" sections and to a depth of approximately 20 meters beneath the "b" section (Plates 45-47).

PERIMETER WELL DATA

The distribution of actinides in sediments beneath the perimeter of the 216-Z-1A Crib was determined by an examination of analytical data from wells 158, 163-169, and 171-174 (Appendix A). A discussion of actinide distribution determined from these wells is centered around all three sets of east-west isopleth cross sections (A-A', B-B', and C-C') and two sets of north-south cross sections (D-D' and F-F') (Appendix D). Conclusions concerning actinide distribution based on perimeter well data are summarized as follows:

(1) Plutonium and americium contamination is not encountered in sediments less than a depth of 5 meters below the projected bottom of the crib. Contamination, if present, occurs discontinuously with depth beneath this horizon.

(2) The maximum level of total activity encountered in perimeter wells is generally less than 10^3 nCi/g.

(3) In general, there is a direct relationship between plutonium and americium concentrations as indicated in the profiles in Appendix B.

(4) The maximum vertical penetration of contamination is approximately 30 meters below the projected bottom of the crib.

(5) Contamination was encountered in all perimeter wells located at the ends of the laterals (158, 163, 165-169, Figure 4). However, contamination was not detected in wells 6, 7, 85-89, and 172 as indicated by a combination of portable radiation survey instrument measurements, gamma scintillation probe profiles,[8] and laboratory analyses of selected samples. The locations of these eight wells (Figure 4) are considered to define the "maximum" boundary of the lateral spread of contamination as outlined in Figure 3.

PROPOSED DISTRIBUTION MECHANISMS

A discussion of possible mechanisms responsible for the distribution of actinides beneath the 216-Z-1A Crib is based on: 1) characterization well data (Appendices A through D) outlined in the previous two sections; 2) micro-distribution data (a determination of actinide distribution associated with individual sediment grains); 3) preliminary pH and $CaCO_3$ measurements; and 4) actinide research previously conducted at Hanford.[1,5,20-35] Such work indicates that a combination of both "physical" and "chemical" processes are responsible for the current distribution of actinides in sediments underlying the 216-Z-1A Crib. The possible influence of these two processes on the distribution of plutonium and americium are discussed separately.

Activity versus depth profiles (Appendix B) show that the greatest concentration of plutonium within the 216-Z-1A Crib occurs immediately beneath the crib, below the central distributor pipe. A possible physical mechanism responsible for this elevated concentration was first proposed by Ames [20] following a study of samples from the 216-Z-9 Crib. Like the 216-Z-1A Crib, the 216-Z-9 facility also received acidic waste liquid from Z-Plant. Examination of 216-Z-9 samples, using autoradiography, electron

microprobe, and X-ray diffraction techniques, indicated that the "high" concentration of plutonium at the top of the sediment column is due to the presence of PuO_2 particles (particles greater than 70 weight percent PuO_2). It was proposed that such particles were originally present in the waste stream and were filtered out by the sediments comprising the floor of the 216-Z-9 Crib. A similar examination of sediment samples collected from the upper portion of well 149, located at the head of the 216-Z-1A Crib (Figure 4), was conducted by Price and Ames.(36) The results of this study indicated that the same filtering process was responsible for the "high" concentration of plutonium in sediments beneath the central distributor pipe.

The pattern of activity encountered in the 216-Z-1A Crib wells, indicates the spread of waste liquid along boundaries between sedimentary units. This finding suggests that the physical mechanism of unsaturated flow played an important role in the distribution of "nonparticulate" plutonium (i.e. plutonium in solution) in sediments beneath the 216-Z-1A Crib. During conditions of unsaturated flow, when liquid is moving from a finer to a coarser sediment layer, the lateral spread of liquid occurs along the grain-size interfaces. Flow into the coarser layer occurs when retention forces in the finer sediments are less than the combined downward force due to gravity and the attractive forces in the coarser sediments. Lateral flow can also occur when liquid encounters boundaries between coarser to finer sediments partly due to the fact that the hydraulic conductivity (see Glossary) of the finer sediments is less than that of the coarser sediments. A more comprehensive explanation of unsaturated and saturated flow can be found in Baver, Gardner, and Gardner.(37)

Evidence of the effect of unsaturated flow is particularly strong in the "a" section of the crib. Excavation and field measurements carried out as part of this study showed that the waste liquid did not reach the end of the first east lateral. Consequently, contamination encountered at the 15 meter depth level in well 163, located at the end of this lateral, most likely came from the spread of waste liquid along the sand-silt interface encountered at this depth level. Such a conclusion is also supported by the distribution of contamination encountered in wells 173

and 174 located near the center of the first east lateral (Figure 4). A similar pattern of waste distribution was found in well 158, located between the ends of the first and second west laterals.

The interface between the medium to very fine sand unit and the pebbly to very coarse to medium sand unit, located approximately 30 meters beneath the crib (Plates 45-47), marks the deepest penetration of activity greater than 10^{-2} nCi/g (total activity). Analyses of samples collected below this depth, as determined by LFE, contain activity less than 10^{-5} nCi/g (total activity). Based on this data, it can be proposed that the boundary between the two sand units served as a natural "barrier". Due to the principles of unsaturated flow, the waste liquid was more prone to spread laterally in the medium to very fine sand unit than to move to the deeper, pebbly very coarse to medium sand unit.

Previous Hanford laboratory studies[1] have noted the effect of pH on the behavior of plutonium in sediments. The results of this study also indicate that the distribution of "nonparticulate" plutonium beneath the 216-Z-1A Crib was dependent upon "chemical" processes involving a change in pH. Work by Price and Ames [36] showed that "nonparticulate" plutonium appears to have been partially removed from the liquid waste in conjunction with silicate hydrolysis reactions which occurred when the acidic waste solutions came in contact with portions of the sand-to-silt sized sediment fragments. The specifics of this reaction are summarized as follows:[36]

> Plutonium detected deeper within the sediment profile (below 1-m depth) was probably contained in the original waste liquids as Pu (IV) in solution.
>
> Examination of selected sediment samples revealed that the "nonparticulate" Pu was partially removed in conjunction with silicate hydrolysis reactions which occurred when the acidic waste solutions came in contact with portions of the sand-to-silt-sized rock fragments. Especially susceptible to hydrolysis reactions were the glassy portions of the basalt fragments. The basalt fragments generally comprise 30 percent of the total volume of the sediments while the other 70 percent is composed of relatively low-grade metamorphics with some granitic igneous rock fragments.
>
> An oversimplified example of such a hydrolysis reaction on a mineralogic scale would be the following reaction with anorthite feldspar:
>
> $$CaAl_2Si_2O_8 + 2H^+ \rightleftharpoons H_2Al_2Si_2O_8 + Ca^{2+}$$

In the initial step of this alteration process, the feldspar aluminosilicate framework is essentially left intact. No Si or Al are solubilized.

The hydrolysis process results in two Pu depositional areas, proposed as due to solution pH rise. One of the depositional areas is in each rock fragment at the interface between (Ca, Na) - feldspar or glass and (H) - feldspar or (H) - glass. Due to diffusion of alkali cations across the altered zone, the pH may rise from 2 or less in the solution to about 9 in the fresh feldspar or glass. The other depositional area may be in the solution exterior to the rock fragments. As the solution proceeds down the sediment column, the pH of the solution rises as the hydrogen ions are removed by the many on-going hydrolysis reactions. Concomitantly the solution content of alkaline earth metal and alkali may be precipitated as polymer, $Pu(OH)_{n}^{+4-n}$, carrying a positive charge. The final product is $Pu(OH)_4$ or PuO_2 . The Pu(IV) polymer is formed irreversibly. Microprobe analyses tend to confirm that the Pu contained in altered zones of rock fragments is not associated with any single element or combination of elements. The Pu appears to occur in all altered rock fragment zones where a rise in pH could have occurred due to the hydrolysis reaction.

The hydrolysis reaction would be expected to occur to a greater extent in portions of the sediment column containing a higher percentage of fines. The fines provide a greater surface area available for reaction. The increase in plutonium concentration noted in silt lenses at depth beneath the 216-Z-1A Crib can perhaps be attributed to the surface area factor.

Preliminary work indicates that a second "chemical" mechanism, also involving a change in pH, may have influenced the deposition of "nonparticulate" plutonium beneath the 216-Z-1A Crib. Carbonate analysis of uncontaminated sediment samples submitted for granulometric analysis show that all but a few samples from each well contain greater than 0.5 percent $CaCO_3$. It was determined that a simple acid reaction test using 10 percent HCl is also capable of detecting the presence of $CaCO_3$ in these sediments. The acid reaction test was performed on contaminated sediments from the upper 20 meters of well 175; these samples showed no $CaCO_3$ reaction. In addition, the pH determined for the samples tested from the contaminated zone measured less than 4. In the same well, the pH of an uncontaminated sample collected from the 21-meter depth measured greater

than 7.5 and showed a positive $CaCO_3$ reaction. Based upon this initial finding, the reaction of acid waste solution with $CaCO_3$ in the sediments, $CaCO_{3(s)} + 2H^{+}_{(aq)} \rightleftharpoons CO_{2\ (g)} + Ca^{+2}_{\ (aq)} + H_2O_{(l)}$, removed $CaCO_3$ from the system and raised the pH of the waste solution. It is proposed that this pH increase, resulting in plutonium precipitation, could have been a possible mechanism contributing to the deposition of plutonium beneath the 216-Z-1A Crib.

Another possible mechanism by which plutonium could have been distributed in the sediments beneath the 216-Z-1A Crib involves the association of plutonium with the organic component of the waste effluent. The organic liquid was used as a plutonium complexant in the separation process and, upon degradation, was released to the crib. Laboratory studies conducted by Knoll[1,29] indicated that Hanford soil removed ^{239}Pu poorly from some organics and not at all from others.

The bulk of the americium upheld in the 216-Z-1A Crib sediments was apparently contained in the original waste stream. This conclusion is based on a calculation of $^{241}Am/^{239,240}Pu$ ratios for samples collected from the crib. The present ratio throughout most of the waste envelope is 1.0, approximately 10 times greater than the ratio that would be produced solely by the in situ decay of ^{241}Pu. Examination of both the concentration profiles in Appendix B and the isopleth cross sections in Appendix D, shows that both plutonium and americium have the same general distribution in the sediments beneath the 216-Z-1A Crib. The observed positive relationship between plutonium and americium distribution suggests the possibility that the same physical and chemical mechanisms were responsible for the deposition of both these actinides.

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CONCLUSIONS

The data contained in this document defines the current pattern of actinide distribution in sediments underlying the 216-Z-1A Crib. This data base can be employed as a guide for continued monitoring of the waste plume beneath the crib, and for management decisions concerned with the future disposition of the facility. Of equivalent importance, is the drilling, sampling, and application of analytical techniques which were innovated to acquire this data base. Not only can the developed methodologies be employed to conduct further study of the 216-Z-1A Crib, but also to carry out characterization work at other Hanford liquid waste disposal facilities as well.

Conclusions concerning the distribution of actinides beneath the 216-Z-1A Crib, based on the data presented in this document, are summarized as follows:

1) The distribution patterns of plutonium and americium contamination in sediments beneath the 216-Z-1A Crib are similar.
2) The highest measured concentration of plutonium (approximately 4×10^4 nCi/g) and americium (approximately 2.5×10^3 nCi/g) occurs in sediments located immediately beneath the central distributor pipe. The "high" concentration of actinides at this location is possibly due to the filtering by sediments of PuO_2 particles which were originally present in the waste stream.
3) The concentration of plutonium and americium in sediments generally decreases with depth beneath the bottom of the crib. An increase in plutonium and americium concentration at depth is generally associated with an increase in the silt content of sediments or with boundaries between sedimentary units.
4) The bulk of the actinide contamination appears to be contained within the first 15 meters of sediments beneath the bottom of the crib. The maximum vertical penetration of plutonium and americium contamination (defined by the 10^{-2} nCi/g isopleth) is approximately 30 meters below the bottom of the facility, or approximately 30 meters above the water table. Samples analyzed by LFE from below this depth contain activity less than 10^{-5} nCi/g.

5) The distribution of activity in wells around the perimeter of the crib is discontinuous with depth. On the basis of perimeter well data, it can be concluded that the waste was released to the ground within a few meters of the central distributor pipe and spread laterally along boundaries between sedimentary units. It is proposed the the lateral spread of waste liquid away from the center of the crib was produced as a result of unsaturated flow of the waste liquid through the layered sediments. Based on data from perimeter wells, the lateral spread of the waste front was limited within a 10-meter wide zone around the perimeter of the crib.
6) The current pattern of waste distribution beneath the 216-Z-1A Crib may be attributable not only to physical mechanisms (i.e. sediment filtration and unsaturated flow), but also to chemical reactions which effected an increase in the pH of the waste liquid. Suggested chemical reactions which may have been responsible for such a change include: 1) silicate hydrolysis reactions between the acidic waste liquid and the sediments; and 2) neutralization of the acidic waste liquid by the $CaCO_3$ in the sediments.

In summary, the information obtained from the current 216-Z-1A Crib characterization effort provides "real-world" measurements of the distribution of plutonium and americium in Hanford sediments. This information can be used to establish parameters essential for the development of viable actinide behavior models. Such models can be further refined as additional field data are acquired.

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GLOSSARY

Activity - The number of nuclear transformations occurring in a given quantity of material per unit of time.

Casing - Tubing, generally of cylindrical form, riveted, welded, or screwed together and lowered into a bore hole during or after drilling to support the sides of the well to prevent the walls from caving.(38)

Contamination (contaminated material) - The deposition, solvation, or infiltration of radionuclides on or into an object, material, or area whereupon the area, material, or object is considered contaminated.(1)

Containment - Use of physical barriers to prevent the release of radioactive contaminants to the uncontrolled environment.

Crib - A buried system for dispersing liquid to allow percolation into the ground.

Cross-contamination - A process by which contamination is introduced into essentially "clean" sediments.

Curie (Ci) - A unit of radioactivity defined as the amount of radioactive material that has an activity of 3.7×10^{10} disintegrations per second (d/s); millicurie (mCi) = 10^{-3} curie; microcurie (μCi) = 10^{-6} curie; nanocurie (nCi) = 10^{-9} curie; picocurie (pCi) = 10^{-12} curie; femtocurie (fCi) = 10^{-15} curie.(1)

Drill Log - Notes maintained by the well driller or geologist describing sediment characteristics, sample localities, portable radiation survey instrument readings, and progress of drilling.

Greenhouse - Plastic enclosure surrounding a work area used as a barrier to radiation release.

Hydraulic Conductivity - The parameter relating the volumetric flux to the driving force in flow through a porous media (particularly water through soil); a function of both the porous medium and the properties of the fluid.(1)

Portable Radiation Survey Instruments - A group of radiation detection instruments that can be used in the field. As used in this report, the term refers specifically to the "poppy" and "PAM", which are used to detect alpha radiation, and the "GM" which is used to detect gamma radiation.

Sealed Out - The techniques by which objects can be removed from a total containment area.

Specific Retention - As used at Hanford, specific retention is defined as that volume of waste liquid that may be disposed to the soil and be held against the force of gravity by the molecular attraction between sand grains and the surface tension of the water, when expressed as percent of packed soil volume. In practice the volume of liquid that may be discharged to a disposal site of known dimensions without leakage to the groundwater expressed as a percent of the total volume of a column of soil with the same cross section as the crib, and extending from the bottom of the crib to the water table.(39)

Telescoped - The use of progressively smaller diameter casing as a well is deepened.

Total Activity - The quantity of $^{239,240}Pu$ expressed in nCi/g of sediment plus the quantity of ^{241}Am expressed in nCi/g of sediment.

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APPENDIX A
ANALYTICAL RESULTS

Appendix A presents the results of all plutonium and americium analyses conducted on 216-Z-1A sediment samples. Combined ^{239}Pu and ^{240}Pu concentrations, ^{241}Am concentrations, and counting standard deviations (sigma) are presented. Concentrations are listed in the same format as reported by the individual laboratories (see pages 33-35). All "less than" concentrations reported in Appendix A are identified with an asterisk. A "less than" concentration is defined as the upper limit of the 99 percent confidence interval around the concentration determined.

WELL 299-W18-85

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
18.3	1.35E-05	(3.51E-06)	[LFE]	*7.66E-06	(4.82E-06)	[LFE]
24.4	*5.86E-06	(3.10E-06)	[LFE]	*9.46E-06	(5.73E-06)	[LFE]
30.5	*0.00E 00	(3.15E-06)	[LFE]	*7.21E-06	(6.41E-06)	[LFE]

WELL 299-W18-86

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
18.3	*1.08E-05	(7.46E-06)	[LFE]	*5.86E-06	(3.69E-06)	[LFE]
30.5	*4.50E-06	(2.66E-06)	[LFE]	*5.41E-06	(4.05E-06)	[LFE]
44.2	2.21E-05	(4.64E-06)	[LFE]	*-1.44E-05	(9.37E-06)	[LFE]

WELL 299-W18-87

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g.)	(sigma)	
9.1	1.98E-05	(4.36E-06)	[LFE]	* 7.21E-06	(4.11E-06)	[LFE]
21.3	*4.95E-06	(4.66E-06)	[LFE]	*-4.50E-06	(4.23E-06)	[LFE]
25.9	*2.25E-06	(2.91E-06)	[LFE]	*-4.50E-06	(4.64E-06)	[LFE]
44.2	*1.26E-05	(7.44E-06)	[LFE]	*-7.21E-06	(6.41E-06)	[LFE]

WELL 299-W18-88

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
9.1	*9.01E-06	(7.66E-06)	[LFE]	*-1.40E-05	(5.86E-06)	[LFE]
16.8	9.00E-05	(9.19E-07)	[LFE]	*-4.95E-06	(4.86E-06)	[LFE]
41.1	5.18E-05	(6.73E-06)	[LFE]	* 0.00E 00	(4.50E-06)	[LFE]

WELL 299-W18-149

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
3.4	3.82E 04	(3.82E 02)	[RHO]	2.59E 03	(2.30E 00)	[RHO]
3.7	8.24E 03	(2.47E 02)	[RHO]	5.09E 02	(1.30E 00)	[RHO]
4.0	6.71E 03	(2.21E 02)	[RHO]	3.86E 02	(1.20E 00)	[RHO]
4.3	2.08E 04	(3.96E 02)	[RHO]	1.31E 03	(2.10E 00)	[RHO]
4.6	1.30E 03	(9.62E 01)	[RHO]	7.00E 01	(5.00E-01)	[RHO]
4.9	2.18E 03	(1.23E 02)	[RHO]	5.57E 01	(4.00E-01)	[RHO]
5.2	3.12E 02	(3.31E 01)	[RHO]	2.31E 01	(1.90E-01)	[RHO]
5.5	7.43E 02	(5.45E 00)	[PNL]	1.34E 02	(2.79E-01)	[PNL]
5.8	*1.88E 02	(0.00E 00)	[RHO]	1.34E 01	(1.50E-01)	[RHO]
6.1	2.93E 02	(8.50E 00)	[RHO]	9.77E 01	(1.60E-01)	[RHO]
6.4	4.77E 01	(3.48E 00)	[RHO]	3.46E 01	(1.50E-01)	[RHO]
6.7				1.10E 01	(1.30E-01)	[RHO]
6.9				1.39E 01	(1.50E-01)	[RHO]
7.3	1.59E 01	(2.18E 00)	[RHO]	7.24E 00	(1.10E-01)	[RHO]
7.6				9.35E 00	(1.20E-01)	[RHO]
8.2	1.95E 00	(4.91E-01)	[PNL]	5.14E 01	(7.21E-02)	[PNL]
8.2				5.72E 00	(9.49E-02)	[RHO]
8.8				3.70E 01	(2.40E-01)	[RHO]
9.3				1.11E-01	(4.39E-03)	[RHO]
9.4				1.91E 01	(1.70E-01)	[RHO]
9.8				1.79E 01	(5.74E-02)	[RHO]

WELL 299-W18-149 (Continued)

DEPTH (meters)	239-240 Pu (nCi/g) (sigma)			241 Am (nCi/g) (sigma)		
10.1				2.10E 01	(6.09E-02)	[RHO]
10.4	2.26E 01	(9.28E-01)	[PNL]	1.34E 01	(6.31E-02)	[PNL]
10.4				7.65E 00	(3.75E-02)	[RHO]
10.7				2.53E 00	(2.20E-02)	[RHO]
11.0				2.61E 00	(2.24E-02)	[RHO]
11.6				1.95E 00	(1.87E-02)	[RHO]
11.9				1.54E 00	(1.68E-02)	[RHO]
12.2				4.14E-01	(7.16E-03)	[RHO]
12.5				5.85E-01	(8.30E-03)	[RHO]
13.7	1.18E 01	(1.77E 00)	[PNL]	1.86E 01	(5.54E-02)	[PNL]
14.3	1.05E 02	(7.52E 00)	[PNL]	1.26E 02	(2.66E-01)	[PNL]
14.3				1.96E 01	(5.48E-02)	[RHO]
15.2	*-2.78E-02	(1.52E-02)	[PNL]	1.83E-02	(3.26E-04)	[PNL]
16.2	*6.67E-03	(9.64E-03)	[PNL]	9.95E-04	(7.97E-05)	[PNL]
16.8	*-8.92E-05	(9.28E-03)	[PNL]	6.44E-04	(6.62E-05)	[PNL]
17.4				7.12E-02	(2.66E-03)	[RHO]
17.5				9.29E-02	(3.33E-03)	[RHO]
18.3	*-4.20E-03	(1.07E-02)	[PNL]	2.99E-03	(1.34E-04)	[PNL]
18.3	5.50E-01	(4.95E-02)	[PNL]	1.82E-01	(1.01E-03)	[PNL]
18.4				6.59E-02	(8.56E-04)	[RHO]
18.7				4.84E-02	(7.45E-04)	[RHO]
19.1				7.65E-02	(9.48E-04)	[RHO]
19.8	*1.26E-02	(9.01E-03)	[PNL]	*4.86E-05	(3.20E-05)	[PNL]

WELL 299-W18-149 (Continued)

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
20.0				1.55E-02	(4.01E-04)	[RHO]
20.4				2.09E-02	(4.77E-04)	[RHO]
21.3	*3.06E-05	(2.24E-02)	[PNL]	5.32E-02	(5.45E-04)	[PNL]
21.6				1.54E-02	(4.13E-04)	[RHO]
21.9				2.22E-02	(5.29E-04)	[RHO]
23.2				2.04E-02	(4.92E-04)	[RHO]
24.4				4.46E-02	(7.09E-04)	[RHO]
24.7	*2.59E-02	(1.49E-02)	[PNL]	1.70E-02	(3.60E-04)	[PNL]
25.9	*2.50E-03	(8.78E-03)	[PNL]	*1.46E-04	(4.23E-05)	[PNL]
26.8				1.72E-02	(4.38E-04)	[RHO]
27.4	*1.35E-03	(9.86E-03)	[PNL]	1.80E-03	(1.08E-04)	[PNL]
27.4				1.69E-02	(6.47E-04)	[RHO]
27.7				2.02E-02	(5.29E-04)	[RHO]
28.7				1.62E-02	(6.53E-04)	[RHO]
29.0				1.44E-02	(5.66E-04)	[RHO]

WELL 299-W18-150

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
2.4	*4.35E-01	(0.00E 00)	[RHO]	1.31E-01	(8.88E-03)	[RHO]
2.9	2.73E 01	(4.37E 00)	[RHO]	7.47E-01	(8.22E-03)	[RHO]
2.9	3.08E 00	(3.07E-01)	[RHO]	2.12E-01	(5.84E-03)	[RHO]
4.0	4.36E 03	(4.80E 01)	[RHO]	7.24E 00	(1.30E-02)	[RHO]
4.6	1.15E 03	(2.41E 01)	[RHO]	1.64E 00	(5.91E-03)	[RHO]
4.7	5.30E 02	(1.64E 01)	[RHO]	1.08E 01	(3.77E-02)	[RHO]
4.9	1.70E 00	(2.55E-01)	[RHO]	4.34E 00	(1.48E-02)	[RHO]
5.3	3.16E 01	(1.36E 00)	[RHO]	1.42E 01	(4.41E-02)	[RHO]
5.3	3.22E 02	(1.42E 01)	[RHO]	5.74E 00	(2.98E-02)	[RHO]
5.6				5.52E 00	(1.05E-02)	[RHO]
5.6	5.74E 02	(1.78E 01)	[RHO]	3.60E 01	(6.84E-02)	[RHO]
6.1	6.53E 02	(2.22E 01)	[RHO]	4.59E 01	(8.73E-02)	[RHO]
6.2	4.22E 01	(1.60E 00)	[RHO]	4.24E 01	(7.21E-02)	[RHO]
6.4	3.26E 02	(1.44E 01)	[RHO]	1.81E 01	(5.06E-02)	[RHO]
6.4	3.71E 02	(4.08E 01)	[RHO]	2.01E 02	(6.42E-01)	[RHO]
6.7	1.11E 02	(8.56E 00)	[RHO]	1.16E 01	(3.73E-02)	[RHO]
7.3	2.30E 02	(3.45E 01)	[RHO]	1.60E 02	(5.76E-01)	[RHO]
7.5	8.59E 02	(6.01E 01)	[RHO]	3.68E 02	(8.84E-01)	[RHO]
8.2	7.12E 01	(6.90E 00)	[RHO]	3.41E 00	(2.01E-02)	[RHO]
9.1	*1.24E 02	(0.00E 00)	[RHO]	4.30E 01	(4.21E-01)	[RHO]
9.1				2.52E 00	(1.67E-02)	[RHO]

WELL 299-W18-150 (Continued)

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
9.4	1.29E 00	(3.11E-01)	[RHO]	8.06E 00	(2.98E-02)	[RHO]
11.6	3.39E 00	(4.40E-01)	[RHO]	2.72E 01	(4.90E-02)	[RHO]
11.7	3.01E 00	(6.39E-01)	[RHO]	3.65E 01	(7.31E-02)	[RHO]
12.0	2.01E 00	(5.03E-01)	[RHO]	2.34E 01	(5.85E-02)	[RHO]
12.3	2.40E 00	(5.76E-01)	[RHO]	2.56E 01	(6.16E-02)	[RHO]
13.0 *	2.88E 00	(0.00E 00)	[RHO]	2.49E 01	(6.48E-02)	[RHO]
13.3	2.14E 00	(5.14E-01)	[RHO]	2.05E 01	(4.93E-02)	[RHO]
13.6 *	8.24E-01	(0.00E 00)	[RHO]	1.68E 01	(4.37E-02)	[RHO]
14.2 *	7.65E-01	(0.00E 00)	[RHO]	2.04E 01	(4.88E-02)	[RHO]
14.5 *	1.53E 00	(0.00E 00)	[RHO]	2.74E 01	(6.02E-02)	[RHO]
21.2 *	1.76E-01	(8.70E-02)	[PNL]	1.01E 00	(2.30E-03)	[PNL]
25.0 *	1.39E-01	(5.40E-02)	[PNL]	3.10E-01	(1.26E-03)	[PNL]
26.1 *-	1.80E-01	(1.10E-02)	[PNL]	1.90E-03	(1.08E-04)	[PNL]
26.5 *	1.50E-02	(7.92E-03)	[PNL] *	1.32E-04	(4.68E-05)	[PNL]
28.7 *	3.90E-02	(4.20E-02)	[PNL]	2.30E-01	(1.10E-03)	[PNL]
29.7 *	3.40E-02	(2.20E-02)	[PNL]	4.50E-02	(4.86E-04)	[PNL]
34.1 *-	3.02E-03	(6.03E-03)	[PNL]	2.18E-04	(4.36E-05)	[PNL]
34.7 *	1.03E-02	(7.11E-03)	[PNL] *	1.66E-04	(8.55E-05)	[PNL]
35.7 *-	1.00E-02	(7.47E-03)	[PNL] *-	7.52E-05	(3.15E-05)	[PNL]
36.6 *	1.33E-02	(9.82E-03)	[PNL]	4.00E-04	(6.04E-05)	[PNL]
36.6	2.02E-02	(5.67E-03)	[PNL] *-	1.48E-05	(3.15E-05)	[PNL]

WELL 299-W18-150 (Continued)

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
37.8	* 1.69E-02	(8.86E-03)	[PNL]	* 1.40E-05	(3.92E-05)	[PNL]
37.8	* 0.00E 00	(3.60E-06)	[LFE]	* 0.00E 00	(7.66E-06)	[LFE]
39.0	*-6.01E-03	(8.51E-03)	[PNL]	*-1.98E-05	(3.33E-05)	[PNL]
39.0	* 5.41E-06	(4.05E-06)	[LFE]	7.03E-05	(7.73E-06)	[LFE]

WELL 299-W18-158

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
6.1	*6.76E-03	(0.00E 00)	[PNL]	*2.39E-05	(0.00E 00)	[PNL]
13.1	*7.39E-03	(0.00E 00)	[PNL]	*1.04E-05	(8.56E-06)	[PNL]
15.2	3.76E-02	(2.97E-03)	[PNL]	2.07E-03	(2.70E-05)	[PNL]
19.8	*7.03E-03	(0.00E 00)	[PNL]	*2.34E-05	(8.56E-06)	[PNL]
24.4	*6.35E-03	(0.00E 00)	[PNL]	*2.12E-05	(8.11E-06)	[PNL]
28.3	*4.55E-03	(2.61E-03)	[PNL]	*7.66E-06	(9.91E-06)	[PNL]

WELL 299-W18-159

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
3.4	1.34E 02	(2.41E 01)	[RHO]	3.66E 01	(6.00E-02)	[RHO]
3.4	3.05E 02	(7.12E 00)	[PNL]	5.45E 01	(1.75E-01)	[PNL]
4.0	1.03E 03	(7.46E 01)	[RHO]	9.92E 01	(1.30E-01)	[RHO]
4.7	3.24E 02	(3.56E 01)	[RHO]	6.32E 01	(8.00E-02)	[RHO]
4.7	5.99E 02	(1.30E 01)	[PNL]	7.48E 01	(2.90E-01)	[PNL]
5.5	4.82E 02	(3.76E 01)	[RHO]	7.43E 01	(8.00E-02)	[RHO]
6.4	1.26E 03	(9.83E 01)	[RHO]	9.09E 01	(1.80E-01)	[RHO]
7.2	5.31E 02	(3.82E 01)	[RHO]	6.48E 01	(8.00E-02)	[RHO]
7.9	4.96E 02	(3.92E 01)	[RHO]	7.13E 01	(8.00E-02)	[PHO]
8.7	*4.80E 01	(0.00E 00)	[RHO]	*2.09E 01	(0.00E 00)	[RHO]
8.7	6.80E 00	(1.50E 00)	[PNL]	2.37E 01	(3.65E-02)	[PNL]
9.8	*4.80E 01	(0.00E 00)	[RHO]	2.31E 01	(4.00E-02)	[RHO]
10.5	*5.90E 01	(0.00E 00)	[RHO]	2.16E 01	(4.00E-02)	[RHO]
11.3	*4.50E 01	(0.00E 00)	[RHO]	3.65E 01	(6.00E-02)	[RHO]
11.3	2.99E 01	(3.65E 00)	[PNL]	4.07E 01	(1.25E-01)	[PNL]
12.0	*3.70E 01	(0.00E 00)	[RHO]	3.03E 01	(5.00E-02)	[RHO]
12.8	2.49E 02	(2.74E 01)	[RHO]	5.37E 01	(6.00E-02)	[RHO]
12.8	3.82E 02	(1.12E 01)	[PNL]	6.78E 01	(2.76E-01)	[PNL]
14.3	1.56E 02	(1.22E 01)	[PNL]	4.12E 02	(4.60E-01)	[PNL]
14.5	*2.29E 00	(2.76E 00)	[PNL]	2.67E 01	(1.10E-01)	[PNL]
14.6	5.50E-01	(5.00E-02)	[PNL]	2.80E-01	(1.30E-02)	[PNL]

WELL 299-W18-159 (Continued)

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
17.4		1.59E 02	(7.92E 00) [PNL]		2.26E 02	(3.11E-01) [PNL]
17.8	*-2.50E-01		(1.97E 00) [PNL]		5.18E 00	(8.80E-02) [PNL]
18.6	* 1.03E 00		(4.86E 00) [PNL]		3.08E 01	(2.10E-01) [PNL]
21.0	* 7.81E-03		(6.90E-03) [PNL]		6.17E-04	(5.85E-05) [PNL]
22.9	* 6.48E-04		(1.20E-02) [PNL]		4.90E-03	(1.76E-04) [PNL]
23.2	*-3.91E-03		(9.71E-03) [PNL]		3.65E-03	(1.44E-04) [PNL]
23.8	* 5.23E-03		(1.01E-02) [PNL]		2.06E-03	(1.12E-04) [PNL]
23.8	* 2.21E-02		(9.20E-03) [PNL]		1.27E-03	(1.12E-04) [PNL]
24.7	*-2.20E-03		(6.56E-03) [PNL]		1.10E-03	(7.20E-05) [PNL]
25.0	* 4.26E-03		(8.09E-03) [PNL]		4.61E-03	(1.40E-04) [PNL]
25.0	* 1.40E-02		(1.10E-02) [PNL]		5.71E-03	(1.94E-04) [PNL]
25.9	* 6.98E-03		(3.02E-03) [PNL]		1.88E-03	(3.60E-05) [PNL]
27.0	* 4.90E-03		(6.13E-03) [PNL]	*	1.26E-04	(3.60E-05) [PNL]
28.3	*-6.00E-03		(6.22E-03) [PNL]	*	8.10E-05	(3.15E-05) [PNL]
29.9	*-2.30E-03		(8.78E-03) [PNL]	*-1.62E-05		(2.59E-05) [PNL]
29.9	* 1.83E-02		(9.67E-03) [PNL]	*-5.85E-06		(3.15E-05) [PNL]
31.4	*-3.45E-03		(7.20E-03) [PNL]		1.94E-04	(4.50E-05) [PNL]
33.8	*-1.10E-02		(8.60E-03) [PNL]	*	3.15E-05	(3.15E-05) [PNL]
35.4	* 7.52E-03		(9.55E-03) [PNL]	*	1.80E-05	(3.15E-05) [PNL]
37.2	* 3.87E-03		(7.30E-03) [PNL]	*	1.80E-05	(3.60E-05) [PNL]
39.6	* 1.02E-02		(1.00E-02) [PNL]		5.00E-04	(7.20E-05) [PNL]

WELL 299-W18-163

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
6.1	* 1.08E-03	(6.71E-03)	[PNL]	* 4.76E-05	(3.24E-05)	[PNL]
7.6	* 3.22E-03	(6.41E-03)	[PNL]	*-2.65E-05	(2.61E-05)	[PNL]
11.0	* 4.77E-03	(6.15E-03)	[PNL]	* 4.60E-06	(2.75E-05)	[PNL]
14.0	* 1.10E-02	(5.72E-03)	[PNL]	5.09E-03	(9.01E-05)	[PNL]
15.1	4.30E-01	(1.10E-01)	[PNL]	1.58E 00	(3.10E-02)	[PNL]
16.2	*-2.40E-03	(2.77E-03)	[PNL]	* 3.24E-05	(1.30E-05)	[PNL]
18.3	* 3.32E-03	(7.14E-03)	[PNL]	* 6.30E-05	(3.69E-05)	[PNL]
19.8	* 4.50E-04	(3.60E-03)	[PNL]	1.17E-04	(1.80E-05)	[PNL]
21.3	* 3.34E-03	(8.34E-03)	[PNL]	* 0.00E 00	(3.65E-05)	[PNL]
25.9	* 1.11E-02	(5.23E-03)	[PNL]	* 2.25E-05	(2.25E-05)	[PNL]
28.8	* 4.30E-03	(8.11E-03)	[PNL]	*-4.45E-05	(3.20E-05)	[PNL]
32.0	* 1.07E-02	(9.85E-03)	[PNL]	*-5.90E-05	(4.19E-05)	[PNL]
33.8	1.49E-05	(3.58E-06)	[LFE]	* 4.95E-06	(5.40E-06)	[LFE]
35.1	* 0.00E 00	(3.15E-06)	[LFE]	* 0.00E 00	(3.15E-06)	[LFE]
36.6	*-9.00E-04	(4.90E-03)	[PNL]	* 5.10E-05	(2.20E-05)	[PNL]
36.6	* 4.82E-03	(0.00E 00)	[PNL]	* 4.50E-05	(1.80E-05)	[PNL]
36.6	* 0.00E 00	(2.25E-06)	[LFE]	* 0.00E 00	(3.15E-06)	[LFE]
37.9	* 0.00E 00	(2.25E-06)	[LFE]	* 0.00E 00	(4.05E-06)	[LFE]
39.6	* 4.05E-06	(2.47E-06)	[LFE]	* 6.76E-06	(4.12E-06)	[LFE]
41.1	* 1.71E-03	(2.88E-03)	[PNL]	* 1.04E-05	(1.13E-05)	[PNL]
41.1	* 2.25E-06	(2.90E-06)	[LFE]	* 3.60E-06	(3.31E-06)	[LFE]

WELL 299-W18-164

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
3.0	*-3.70E-04	(2.00E-03)	[PNL]	* 1.08E-05	(8.36E-06)	[PNL]
3.0	* 4.05E-06	(3.16E-06)	[LFE]	* 0.00E 00	(9.01E-06)	[LFE]
7.6	* 4.30E-03	(6.60E-03)	[PNL]	*-1.76E-05	(3.87E-05)	[PNL]
9.1	* 5.49E-03	(2.59E-03)	[PNL]	* 4.18E-06	(1.00E-05)	[PNL]
9.1	* 5.41E-03	(3.15E-03)	[PNL]	* 4.05E-06	(9.01E-06)	[PNL]
10.7	* 2.20E-01	(0.00E 00)	[IRT]	* 6.37E-02	(0.00E 00)	[IRT]
10.8	* 4.86E 00	(1.76E 00)	[PNL]	9.50E 00	(5.30E-02)	[PNL]
10.8	* 1.85E 00	(7.56E-01)	[PNL]	9.63E 00	(2.38E 00)	[PNL]
10.8	* 1.03E 00	(6.80E-01)	[PNL]	9.91E 00	(2.34E-02)	[PNL]
10.8	* 7.86E 00	(3.11E 00)	[IRT]	1.92E 01	(4.70E-01)	[IRT]
15.2	*-9.50E-04	(2.30E-03)	[PNL]	5.06E-01	(8.06E-03)	[PNL]
16.8	* 2.40E-01	(0.00E 00)	[IRT]	* 5.38E-02	(0.00E 00)	[IRT]
19.8	*-1.86E-03	(5.18E-03)	[PNL]	*-1.60E-06	(2.29E-05)	[PNL]
19.8	* 2.40E-01	(0.00E 00)	[IRT]	* 6.09E-02	(0.00E 00)	[IRT]
20.7	* 8.18E-01	(3.45E-01)	[IRT]	5.90E-01	(4.89E-02)	[IRT]
21.3	6.17E 00	(7.25E-02)	[PNL]	1.36E 01	(2.39E-02)	[PNL]
21.3	2.02E 01	(3.30E 00)	[PNL]	1.65E 01	(9.55E-02)	[PNL]
21.3	1.76E 01	(3.41E 00)	[PNL]	1.83E 01	(1.00E-01)	[PNL]
21.3	1.39E 01	(3.39E 00)	[PNL]	1.83E 01	(1.00E-01)	[PNL]

WELL 299-W18-164 (Continued)

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
21.3	*9.50E 00	(3.52E 00)	[PNL]	1.91E 01	(1.06E-01)	[PNL]
21.3	1.87E 01	(3.45E 00)	[PNL]	1.83E 01	(1.00E-01)	[PNL]
21.3	*6.94E 00	(3.27E 00)	[PNL]	1.80E 01	(9.95E-02)	[PNL]
21.3	1.36E 01	(3.28E 00)	[PNL]	1.73E 01	(9.82E-02)	[PNL]
21.3	1.54E 01	(3.34E 00)	[PNL]	1.69E 01	(9.68E-02)	[PNL]
21.3	2.77E 01	(3.86E 00)	[PNL]	2.35E 01	(1.14E-01)	[PNL]
21.3	*6.40E 00	(3.51E 00)	[PNL]	1.94E 01	(1.48E-01)	[PNL]
21.3	8.96E 00	(2.49E 00)	[PNL]	1.23E 01	(1.02E-01)	[PNL]
21.3	6.75E 00	(7.90E-01)	[PNL]	1.36E 01	(2.38E-02)	[PNL]
21.3	*1.25E 00	(4.02E-01)	[IRT]	4.00E-01	(5.70E-02)	[IRT]
21.8	3.84E 01	(6.26E 00)	[PNL]	6.48E 01	(1.93E-01)	[PNL]
21.8	4.59E 01	(1.86E 00)	[PNL]	6.04E 01	(5.86E-02)	[PNL]
21.8	5.68E 01	(5.32E 00)	[IRT]	4.41E 01	(4.93E-01)	[IRT]
21.8	*1.24E 00	(0.00E 00)	[IRT]	2.54E 00	(1.68E-01)	[IRT]
21.8	6.95E 00	(1.46E 00)	[IRT]	3.22E 00	(2.09E-01)	[IRT]
21.8	7.36E 00	(1.43E 00)	[IRT]	3.44E 00	(2.02E-01)	[IRT]
21.8	*1.75E 00	(1.43E 00)	[IRT]	3.48E 00	(2.02E-01)	[IRT]
22.1	6.37E 01	(5.59E 00)	[IRT]	3.51E 01	(6.53E-01)	[IRT]
22.9	*0.00E 00	(2.10E 00)	[PNL]	3.45E 00	(6.12E-02)	[PNL]
22.9	*5.00E-01	(3.90E-01)	[PNL]	3.56E 00	(1.09E-02)	[PNL]
22.9	*3.04E-01	(1.40E-01)	[PNL]	3.73E 00	(4.95E-03)	[PNL]

WELL 299-W18-164 (Continued)

DEPTH (meters)		239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
22.9	*	9.87E 00	(3.13E 00)	[IRT]	1.22E 01	(4.29E-01)	[IRT]
23.2	*	3.64E-01	(1.47E-01)	[IRT]	*5.05E-02	(0.00E 00)	[IRT]
24.4	*	3.36E-01	(0.00E 00)	[IRT]	*1.03E-01	(4.03E-02)	[IRT]
25.0	*	2.68E-02	(2.27E-02)	[PNL]	7.49E-02	(5.99E-04)	[PNL]
25.0	*	3.35E-01	(2.00E-01)	[IRT]	*7.30E-02	(0.00E 00)	[IRT]
25.9	*	2.58E 00	(3.55E 00)	[PNL]	2.71E 01	(1.11E-01)	[PNL]
25.9		6.70E 00	(1.18E 00)	[PNL]	2.94E 01	(3.60E-02)	[PNL]
25.9		6.17E 00	(1.08E 00)	[PNL]	2.94E 01	(3.60E-02)	[PNL]
25.9		1.56E 01	(3.17E 00)	[IRT]	1.69E 01	(4.07E-01)	[IRT]
26.5		8.09E 01	(1.03E 01)	[PNL]	2.52E 02	(4.35E-01)	[PNL]
27.1		1.17E 02	(8.50E 00)	[PNL]	1.59E 02	(3.45E-01)	[PNL]
27.1		7.90E 01	(1.25E 01)	[IRT]	1.08E 02	(1.07E 00)	[IRT]
28.0		1.74E 01	(2.30E 00)	[PNL]	2.64E 01	(6.84E-02)	[PNL]
28.0		1.76E 01	(1.17E 00)	[PNL]	2.91E 01	(3.49E-02)	[PNL]
28.0		1.62E 01	(1.07E 00)	[PNL]	2.91E 01	(3.51E-02)	[PNL]
30.6	*	3.01E 00	(1.81E 00)	[IRT]	6.37E 00	(2.50E-01)	[IRT]
32.0	*	-6.30E-04	(3.25E-03)	[PNL]	9.59E-04	(3.51E-05)	[PNL]
32.0	*	9.91E-06	(8.13E-06)	[LFE]	*0.00E 00	(4.50E-06)	[LFE]
32.6	*	2.70E-01	(0.00E 00)	[IRT]	*6.00E-02	(0.00E 00)	[IRT]
35.1	*	1.80E-06	(1.44E-04)	[LFE]	*0.00E 00	(4.50E-06)	[LFE]
36.6	*	1.05E-03	(2.07E-03)	[PNL]	*1.08E-05	(8.68E-06)	[PNL]

WELL 299-W18-164 (Continued)

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
36.6	* 1.04E-03	(2.07E-03)	[PNL]	* 9.91E-06	(8.11E-06)	[PNL]
36.6	* 9.91E-06	(2.97E-06)	[LFE]	* 0.00E 00	(4.50E-06)	[LFE]
39.0	* 6.26E-03	(3.02E-03)	[PNL]	*-1.08E-05	(1.26E-05)	[PNL]
39.6	* 0.00E 00	(6.31E-06)	[LFE]	1.44E-05	(2.59E-06)	[LFE]
41.1	* 0.00E 00	(5.41E-06)	[LFE]	* 3.65E-05	(1.06E-05)	[LFE]
42.7	* 9.34E-03	(2.64E-02)	[PNL]	*-4.36E-05	(1.14E-04)	[PNL]
42.7	* 5.41E-06	(2.54E-06)	[LFE]	* 6.31E-06	(3.98E-06)	[LFE]
44.3	* 0.00E 00	(4.95E-06)	[LFE]	* 1.26E-05	(1.12E-05)	[LFE]
45.7	*-4.72E-03	(8.19E-03)	[PNL]	* 4.77E-05	(3.47E-05)	[PNL]
45.7	* 0.00E 00	(2.70E-06)	[LFE]	3.47E-05	(5.90E-06)	[LFE]
46.8	* 2.25E-06	(1.40E-06)	[LFE]	* 1.76E-05	(7.53E-06)	[LFE]

WELL 299-W18-165

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
4.6	* 1.33E-03	(2.39E-03)	[PNL]	* 1.71E-05	(1.80E-05)	[PNL]
6.1	* 4.21E-01	(0.00E 00)	[IRT]	* 8.45E-02	(0.00E 00)	[IRT]
7.9	* 0.00E 00	(8.45E-03)	[PNL]	* 1.08E-05	(2.56E-05)	[PNL]
9.1	*-1.20E-02	(9.45E-03)	[PNL]	* 4.41E-05	(3.74E-05)	[PNL]
9.1	* 2.81E-01	(0.00E 00)	[IRT]	* 6.17E-02	(0.00E 00)	[IRT]
10.7	* 2.19E-01	(0.00E 00)	[IRT]	* 6.48E-02	(0.00E 00)	[IRT]
14.3	* 1.15E-02	(7.96E-03)	[PNL]	* 0.00E 00	(2.97E-05)	[PNL]
16.2	4.15E 00	(9.59E-02)	[PNL]	4.86E-01	(1.67E-03)	[PNL]
16.2	6.19E 00	(6.12E-01)	[IRT]	5.12E-01	(7.95E-02)	[IRT]
17.4	3.13E 00	(9.73E-02)	[PNL]	2.21E-01	(1.44E-03)	[PNL]
17.4	* 3.53E-01	(1.88E-01)	[IRT]	* 5.96E-02	(0.00E 00)	[IRT]
18.4	2.74E-01	(2.52E-02)	[PNL]	2.41E-02	(3.69E-04)	[PNL]
19.8	* 2.45E-01	(0.00E 00)	[IRT]	* 6.78E-02	(0.00E 00)	[IRT]
21.3	* 8.06E-03	(8.54E-03)	[PNL]	*-1.00E-05	(3.46E-05)	[PNL]
23.2	* 1.58E-01	(0.00E 00)	[IRT]	* 4.54E-02	(0.00E 00)	[IRT]
24.4	* 0.00E 00	(8.45E-03)	[PNL]	* 2.16E-05	(3.15E-05)	[PNL]
26.1	* 2.11E-01	(0.00E 00)	[IRT]	* 5.42E-02	(0.00E 00)	[IRT]
27.4	* 5.75E-03	(8.68E-03)	[PNL]	* 5.90E-06	(3.46E-05)	[PNL]
27.4	* 2.83E-01	(0.00E 00)	[IRT]	* 5.86E-02	(0.00E 00)	[IRT]
27.7	1.96E 02	(3.84E 01)	[PNL]	2.87E 02	(9.96E-01)	[PNL]
27.7	* 1.00E 00	(0.00E 00)	[IRT]	1.86E 00	(1.30E-01)	[IRT]

WELL 299-W18-165 (Continued)

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
28.3	4.82E 02	(5.77E 01)	[PNL]	7.93E 02	(1.65E 00)	[PNL]
29.3	2.48E 00	(6.63E-01)	[PNL]	7.85E-01	(1.40E-02)	[PNL]
29.9	6.98E 00	(1.90E 00)	[PNL]	1.14E 01	(6.98E-02)	[PNL]
32.5	*3.03E-01	(2.95E-01)	[IRT]	* 9.73E-02	(0.00E 00)	[IRT]
33.8	*0.00E 00	(9.63E-03)	[PNL]	* 5.40E-06	(4.36E-06)	[PNL]
33.8	*4.50E-06	(2.79E-06)	[LFE]	5.86E-05	(1.29E-05)	[LFE]
35.1	*0.00E 00	(3.60E-06)	[LFE]	5.14E-05	(9.25E-06)	[LFE]
37.5	*5.75E-03	(9.96E-03)	[PNL]	* 1.35E-04	(4.50E-05)	[PNL]
40.5	*2.70E-06	(3.94E-06)	[LFE]	* 3.60E-06	(3.46E-06)	[LFE]
41.1	*0.00E 00	(1.40E-02)	[PNL]	*-5.90E-06	(2.84E-05)	[PNL]
41.1	*0.00E 00	(2.70E-06)	[LFE]	* 0.00E 00	(8.11E-06)	[LFE]

WELL 299-W18-166

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
1.5	* 1.35E-05	(5.00E-06)	[LFE]	* 5.86E-06	(4.57E-06)	[LFE]
6.1	* 1.30E-02	(9.14E-03)	[PNL]	* 7.67E-05	(2.84E-05)	[PNL]
13.6	* 0.00E 00	(9.63E-03)	[PNL]	* 7.02E-05	(3.15E-05)	[PNL]
15.2	* 3.44E-03	(6.03E-03)	[PNL]	* 0.00E 00	(3.70E-05)	[PNL]
15.2	* 2.51E-01	(0.00E 00)	[IRT]	* 5.25E-02	(0.00E 00)	[IRT]
16.8	* 0.00E 00	(9.50E-03)	[PNL]	* 4.32E-05	(3.60E-05)	[PNL]
18.3	*-2.21E-03	(8.73E-03)	[PNL]	* 5.30E-05	(4.14E-05)	[PNL]
18.3	* 3.39E-01	(0.00E 00)	[IRT]	1.51E-01	(4.20E-02)	[IRT]
19.8	* 8.06E-03	(7.70E-03)	[PNL]	*-7.08E-05	(3.28E-05)	[PNL]
19.8	* 4.97E-01	(0.00E 00)	[IRT]	* 8.74E-02	(0.00E 00)	[IRT]
20.3	* 0.00E 00	(8.78E-03)	[PNL]	*-3.54E-05	(3.46E-05)	[PNL]
22.3	1.00E-01	(8.06E-03)	[PNL]	* 2.70E-05	(3.74E-05)	[PNL]
24.1	* 3.69E-01	(0.00E 00)	[IRT]	* 9.12E-02	(0.00E 00)	[IRT]
25.9	* 3.91E-01	(0.00E 00)	[IRT]	* 9.11E-02	(4.98E-02)	[IRT]
27.7	* 6.90E-03	(8.91E-03)	[PNL]	*-1.18E-05	(3.46E-05)	[PNL]
28.3	1.11E 02	(2.54E 01)	[PNL]	1.58E 02	(7.39E-01)	[PNL]
28.3	7.22E 01	(7.39E 00)	[IRT]	5.77E 01	(7.35E-01)	[IRT]
29.1	* 5.90E-01	(0.00E 00)	[IRT]	* 1.42E-01	(6.64E-02)	[IRT]
29.9	*-6.00E-03	(1.10E-02)	[PNL]	5.95E-03	(1.67E-04)	[PNL]
30.5	1.05E 01	(1.53E 00)	[PNL]	9.50E 00	(4.86E-02)	[PNL]
31.7	*-1.07E-03	(1.80E-02)	[PNL]	3.14E-02	(4.23E-04)	[PNL]

WELL 299-W18-166 (Continued)

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
33.5	*2.03E-01	(0.00E 00)	[IRT]	* 5.22E-02	(0.00E 00)	[IRT]
34.9	*4.10E-03	(7.40E-03)	[PNL]	* 2.93E-05	(3.69E-03)	[PNL]
36.4	*2.25E-06	(1.31E-06)	[LFE]	* 0.00E 00	(6.31E-06)	[LFE]
38.1	*2.18E-02	(9.68E-03)	[PNL]	* 1.17E-04	(0.00E 00)	[PNL]
38.1	*8.56E-06	(3.51E-06)	[LFE]	3.42E-05	(6.84E-06)	[LFE]
40.2	*6.76E-06	(4.06E-06)	[LFE]	* 1.22E-05	(7.32E-06)	[LFE]
41.8	3.00E-02	(8.92E-03)	[PNL]	*-5.85E-06	(3.60E-05)	[PNL]
41.8	*4.05E-06	(3.32E-06)	[LFE]	* 0.00E 00	(6.31E-06)	[LFE]

WELL 299-W15-167

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
6.1	*-1.26E-04	(2.53E-03)	[PNL]	* 1.48E-05	(1.09E-05)	[PNL]
13.4	* 5.37E-03	(7.36E-03)	[PNL]	* 4.14E-05	(3.69E-05)	[PNL]
14.8	*-8.33E-03	(5.65E-03)	[PNL]	*-1.81E-05	(2.92E-05)	[PNL]
16.2	*-3.43E-03	(3.46E-03)	[PNL]	* 2.74E-05	(1.22E-05)	[PNL]
16.2	* 2.30E-01	(0.00E 00)	[IRT]	* 7.70E-02	(0.00E 00)	[IRT]
16.8	8.79E 02	(4.39E 01)	[IRT]	4.15E 02	(3.05E 00)	[IRT]
17.1	* 2.09E 00	(7.51E-01)	[IRT]	4.31E-01	(1.10E-01)	[IRT]
17.7	* 1.80E 00	(5.80E-01)	[PNL]	4.10E 00	(2.48E-02)	[PNL]
17.7	* 3.25E-01	(1.05E-01)	[IRT]	4.82E 00	(1.38E-01)	[IRT]
18.3	*-4.40E-02	(1.60E-02)	[PNL]	3.00E-02	(3.96E-04)	[PNL]
18.3	* 1.57E-01	(0.00E 00)	[IRT]	* 3.81E-02	(0.00E 00)	[IRT]
19.5	* 3.36E-01	(0.00E 00)	[IRT]	* 7.03E-02	(4.31E-02)	[IRT]
21.6	*-8.60E-04	(6.67E-03)	[PNL]	* 6.75E-05	(3.42E-05)	[PNL]
23.2	* 4.34E-03	(6.96E-03)	[PNL]	* 7.88E-05	(4.05E-05)	[PNL]
31.1	* 3.15E-06	(4.06E-06)	[LFE]	4.95E-05	(9.41E-06)	[LFE]
31.4	*-4.32E-03	(8.53E-03)	[PNL]	* 1.76E-05	(3.96E-05)	[PNL]
36.9	* 2.70E-06	(3.48E-06)	[LFE]	* 5.86E-06	(7.03E-06)	[LFE]
39.0	*-1.18E-03	(9.32E-03)	[PNL]	* 8.86E-05	(3.87E-05)	[PNL]
40.8	* 0.00E 00	(1.80E-06)	[LFE]	* 0.00E 00	(4.50E-06)	[LFE]

WELL 299-W18-168

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
8.2	*-4.30E-03	(7.44E-03)	[PNL]	*5.85E-06	(2.97E-05)	[PNL]
13.7	* 1.08E-03	(8.11E-03)	[PNL]	*5.85E-06	(3.28E-05)	[PNL]
14.9	* 1.15E 01	(7.36E 00)	[PNL]	1.92E 01	(2.80E-01)	[PNL]
16.2	*-2.33E-03	(3.39E-03)	[PNL]	6.58E-03	(6.48E-05)	[PNL]
17.7	1.36E 02	(1.30E 01)	[PNL]	1.94E 02	(5.20E-01)	[PNL]
19.8	*-1.26E-04	(4.24E-03)	[PNL]	1.79E-03	(1.04E-04)	[PNL]
22.6	* 1.17E-04	(1.05E-02)	[PNL]	*1.24E-04	(4.23E-05)	[PNL]
22.9	* 2.45E-03	(2.92E-03)	[PNL]	7.38E-04	(2.43E-05)	[PNL]
25.9	* 3.82E-04	(2.86E-03)	[PNL]	1.04E-04	(1.53E-05)	[PNL]
29.0	*-9.90E-05	(9.72E-03)	[PNL]	*8.28E-05	(5.13E-05)	[PNL]
33.5	* 0.00E 00	(1.80E-06)	[LFE]	*1.17E-05	(9.59E-06)	[LFE]
34.7	* 7.21E-06	(2.60E-06)	[LFE]	3.42E-05	(6.84E-06)	[LFE]
36.3	* 1.67E-05	(8.85E-06)	[LFE]	*1.26E-05	(4.54E-06)	[LFE]
38.6	* 8.56E-06	(4.71E-06)	[LFE]	1.46E-03	(7.30E-05)	[LFE]

WELL 299-W18-169

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
7.0	* 0.00E 00	(7.02E-03)	[PNL]	*-1.40E-05	(3.06E-05)	[PNL]
7.0	1.25E-04	(1.13E-05)	[LFE]	* 1.35E-06	(1.80E-06)	[LFE]
10.1	*-1.10E-02	(7.89E-03)	[PNL]	* 4.72E-05	(3.24E-05)	[PNL]
11.0	1.39E 01	(3.01E 00)	[PNL]	2.04E 01	(1.20E-01)	[PNL]
11.4	6.84E 01	(4.90E 00)	[PNL]	5.49E 01	(1.40E-01)	[PNL]
13.3	* 6.41E-01	(3.26E-01)	[PNL]	2.21E 02	(1.20E-02)	[PNL]
14.3	* 1.35E-03	(7.11E-03)	[PNL]	1.09E-03	(7.42E-05)	[PNL]
16.3	* 1.26E-03	(2.53E-03)	[PNL]	* 4.00E-06	(1.12E-05)	[PNL]
18.3	* 2.12E-03	(9.00E-03)	[PNL]	* 2.97E-05	(3.87E-05)	[PNL]
20.1	*-1.42E-03	(5.49E-03)	[PNL]	* 6.39E-05	(2.70E-05)	[PNL]
20.1	* 0.00E 00	(3.60E-06)	[LFE]	* 1.04E-05	(4.47E-06)	[LFE]
22.4	*-6.00E-03	(5.93E-03)	[PNL]	* 4.77E-05	(2.74E-05)	[PNL]
26.2	* 5.58E-03	(1.02E-02)	[PNL]	7.29E-04	(7.34E-05)	[PNL]
27.4	*-1.40E-02	(1.15E-02)	[PNL]	2.06E-03	(1.11E-04)	[PNL]
27.7	* 3.22E-03	(5.98E-03)	[PNL]	* 1.77E-05	(4.91E-05)	[PNL]
28.3	* 5.09E-03	(5.49E-03)	[PNL]	* 4.50E-05	(3.20E-05)	[PNL]
28.3	* 7.66E-06	(4.67E-06)	[LFE]	4.46E-05	(7.14E-06)	[LFE]
29.3	* 7.85E-03	(1.15E-02)	[PNL]	2.00E-04	(5.88E-05)	[PNL]
31.7	*-3.38E-03	(5.76E-03)	[PNL]	* 1.94E-05	(3.46E-05)	[PNL]
31.7	* 2.70E-06	(2.38E-06)	[LFE]	* 2.97E-05	(1.13E-05)	[LFE]
33.5	* 1.29E-03	(6.39E-03)	[PNL]	*-3.80E-06	(2.97E-05)	[PNL]

WELL 299-W18-169 (Continued)

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
33.5	* 0.00E 00	(1.80E-06)	[LFE]	1.80E-05	(4.68E-06)	[LFE]
35.1	*-2.62E-03	(6.75E-03)	[PNL]	* 1.89E-05	(2.79E-05)	[PNL]
35.1	* 0.00E 00	(4.50E-06)	[LFE]	* 6.89E-05	(5.42E-05)	[LFE]
36.6	* 1.29E-03	(7.02E-03)	[PNL]	*-1.48E-05	(3.28E-05)	[PNL]
36.6	* 0.00E 00	(3.60E-06)	[LFE]	* 1.26E-05	(9.77E-06)	[LFE]
40.2	* 6.44E-04	(6.84E-03)	[PNL]	*-5.67E-05	(3.28E-05)	[PNL]
40.2	* 2.70E-06	(2.54E-06)	[LFE]	*-7.66E-06	(8.58E-06)	[LFE]

WELL 299-W18-171

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g.)	(sigma)	
13.1	* 1.01E-02	(1.06E-02)	[PNL]	* 7.34E-05	(3.74E-05)	[PNL]
16.2	*-6.20E-03	(1.05E-02)	[PNL]	* 3.92E-05	(3.78E-05)	[PNL]
19.8	* 0.00E 00	(1.10E-02)	[PNL]	*-4.41E-05	(4.00E-05)	[PNL]
20.4	* 5.13E-03	(1.17E-02)	[PNL]	* 1.44E-05	(4.28E-05)	[PNL]
21.0	*-7.30E-03	(9.68E-03)	[PNL]	* 6.34E-05	(4.00E-05)	[PNL]
22.9	*-5.31E-05	(2.30E-03)	[PNL]	*-8.10E-06	(9.00E-06)	[PNL]
22.9	* 0.00E 00	(2.70E-06)	[LFE]	4.50E-05	(6.75E-06)	[LFE]
25.9	*-4.20E-03	(8.04E-03)	[PNL]	*-4.14E-05	(3.89E-05)	[PNL]
26.5	* 7.52E-03	(8.39E-03)	[PNL]	*-2.34E-05	(3.54E-05)	[PNL]
26.8	*-6.20E-03	(1.07E-02)	[PNL]	1.84E-03	(1.08E-04)	[PNL]
27.7	* 0.00E 00	(7.60E-03)	[PNL]	* 1.59E-04	(4.50E-05)	[PNL]
27.7	* 1.35E-06	(1.35E-06)	[LFE]	4.19E-04	(1.68E-05)	[LFE]
29.0	*-1.60E-03	(8.56E-03)	[PNL]	4.77E-04	(5.63E-05)	[PNL]
29.0	* 3.02E-03	(7.39E-03)	[PNL]	5.22E-04	(5.40E-05)	[PNL]
29.0	* 2.25E-06	(2.16E-06)	[LFE]	5.18E-04	(2.59E-05)	[LFE]
38.3	*-1.18E-02	(9.76E-03)	[PNL]	* 8.10E-05	(4.05E-05)	[PNL]
38.3	* 1.80E-06	(2.16E-06)	[LFE]	5.95E-05	(6.55E-06)	[LFE]
40.2	* 9.04E-03	(7.56E-03)	[PNL]	*-3.38E-05	(3.60E-05)	[PNL]
40.2	* 5.86E-06	(2.58E-06)	[LFE]	* 6.31E-06	(2.90E-06)	[LFE]
41.5	*-9.70E-03	(8.64E-03)	[PNL]	* 9.54E-05	(3.60E-05)	[PNL]
41.5	* 0.00E 00	(2.25E-06)	[LFE]	1.80E-05	(4.32E-06)	[LFE]

WELL 299-W18-172

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
22.9	* 1.08E-02	(8.06E-03)	[PNL]	* 9.00E-06	(3.60E-05)	[PNL]
22.9	* 0.00E 00	(1.35E-06)	[LFE]	* 0.00E 00	(2.70E-06)	[LFE]
35.4	*-1.23E-03	(6.16E-03)	[PNL]	*-5.63E-05	(3.20E-05)	[PNL]
35.4	* 1.35E-06	(3.22E-06)	[LFE]	* 7.66E-06	(1.45E-05)	[LFE]
36.9	*-6.12E-03	(7.47E-03)	[PNL]	* 1.80E-05	(3.20E-05)	[PNL]
36.9	* 7.21E-06	(4.04E-06)	[LFE]	* 1.80E-06	(2.45E-06)	[LFE]
38.1	* 3.22E-03	(9.18E-03)	[PNL]	*-4.72E-05	(4.50E-05)	[PNL]
38.1	* 3.60E-06	(2.56E-06)	[LFE]	* 2.25E-06	(3.29E-06)	[LFE]
39.9	* 1.43E-02	(8.19E-03)	[PNL]	*-9.90E-06	(3.60E-05)	[PNL]
39.9	* 8.11E-06	(3.24E-06)	[LFE]	* 3.60E-06	(3.46E-06)	[LFE]
40.8	1.00E-01	(3.15E-03)	[PNL]	* 2.20E-06	(1.40E-05)	[PNL]
40.8	*-4.05E-06	(2.71E-06)	[LFE]	* 4.50E-06	(3.20E-06)	[LFE]

WELL 299-W18-173

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
5.0	2.40E 00	(4.50E-01)	[PNL]	3.89E 00	(1.00E-02)	[PNL]
5.5	* 4.80E-03	(1.85E-02)	[PNL]	3.53E-02	(4.28E-04)	[PNL]
6.4	* 5.36E-03	(9.88E-03)	[PNL]	1.62E-03	(9.45E-05)	[PNL]
7.8	*-4.60E-03	(1.01E-02)	[PNL]	8.60E-04	(7.65E-05)	[PNL]
8.8	* 2.40E 01	(7.70E 00)	[PNL]	7.38E 01	(3.30E-01)	[PNL]
10.5	* 3.20E 01	(1.20E 01)	[PNL]	2.00E 02	(5.50E-01)	[PNL]
12.5	* 9.30E-02	(2.30E-02)	[PNL]	4.20E-02	(4.95E-04)	[PNL]
14.0	5.08E 01	(7.40E 00)	[PNL]	2.09E 02	(3.00E-01)	[PNL]
14.6	* 1.00E-01	(7.60E-02)	[PNL]	7.20E-01	(1.94E-03)	[PNL]
15.5	5.35E 00	(2.24E-01)	[PNL]	7.36E 00	(6.17E-03)	[PNL]

WELL 299-W18-174

DEPTH (meters)		239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
4.9	*	1.46E-01	(5.50E-02)	[PNL]	3.90E-01	(5.13E-04)	[PNL]
6.4	*	1.80E-02	(9.80E-03)	[PNL]	2.58E-03	(1.22E-04)	[PNL]
9.1	*	-4.40E-03	(8.80E-03)	[PNL]	*3.90E-05	(3.82E-05)	[PNL]
10.7		3.38E 01	(9.50E 00)	[PNL]	8.29E 01	(3.06E-01)	[PNL]
11.6	*	3.05E-01	(7.48E-01)	[PNL]	1.09E 01	(2.40E-02)	[PNL]
13.4		3.58E-01	(5.60E-02)	[PNL]	4.90E-01	(1.59E-03)	[PNL]
14.2		1.92E 02	(1.60E 01)	[PNL]	2.24E 02	(5.00E-01)	[PNL]
14.9		2.83E-01	(4.70E-02)	[PNL]	2.08E-01	(1.13E-03)	[PNL]

WELL 299-W18-175

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
5.3	1.24E 02	(5.86E 00)	[PNL]	5.23E-01	(1.71E -01)	[PNL]
7.5	1.16E 02	(6.17E 00)	[PNL]	6.13E 01	(1.86E -01)	[PNL]
8.7	3.47E 01	(6.20E 00)	[PNL]	1.29E 02	(2.70E-01)	[PNL]
10.2	* 4.72E 00	(4.72E 00)	[PNL]	7.97E 01	(1.80E-01)	[PNL]
11.4	8.60E 01	(1.80E 00)	[PNL]	2.04E 01	(3.50E-02)	[PNL]
12.5	9.78E 01	(8.02E 00)	[PNL]	5.27E 01	(2.40E-01)	[PNL]
12.6	1.09E 02	(1.70E 00)	[PNL]	8.20E 00	(2.40E-02)	[PNL]
15.7	9.68E 01	(5.70E 00)	[PNL]	9.00E 01	(2.00E-01)	[PNL]
16.8	2.76E 02	(1.28E 01)	[PNL]	1.30E 02	(3.80E-01)	[PNL]
17.7	5.09E 01	(6.20E 00)	[PNL]	1.22E 02	(2.30E-01)	[PNL]
18.3	7.38E 01	(7.74E 00)	[PNL]	1.37E 02	(3.20E-01)	[PNL]
19.2	1.95E 01	(5.09E 00)	[PNL]	2.67E 01	(1.70E-01)	[PNL]
19.8	2.02E 00	(6.20E-01)	[PNL]	4.10E 00	(1.50E-02)	[PNL]
21.6	* 3.20E-03	(1.57E-02)	[PNL]	3.99E-02	(4.00E-04)	[PNL]
23.5	2.84E 01	(5.13E 00)	[PNL]	9.18E 01	(2.00E-01)	[PNL]
24.1	*-3.90E-02	(5.44E-03)	[PNL]	4.86E-01	(1.58E-03)	[PNL]
25.8	* 8.68E-02	(4.77E-02)	[PNL]	3.12E-01	(1.40E-03)	[PNL]
28.3	* 6.08E 00	(3.40E 00)	[PNL]	3.82E 01	(1.30E-01)	[PNL]
29.0	2.75E 02	(1.61E 01)	[PNL]	2.27E 02	(5.00E-01)	[PNL]
29.3	* 1.70E 01	(8.42E 00)	[PNL]	6.98E 00	(2.80E-01)	[PNL]
30.5	*-1.44E-02	(1.03E-02)	[PNL]	4.77E-03	(1.65E-04)	[PNL]

WELL 299-W18-175 (Continued)

DEPTH (meters)	239-240 Pu (nCi/g)	(sigma)		241 Am (nCi/g)	(sigma)	
32.0	*-3.84E-03	(8.00E-03)	[PNL]	7.52E-04	(7.65E-05)	[PNL]
34.1	*-4.77E-03	(9.75E-03)	[PNL]	1.30E-03	(9.45E-05)	[PNL]
37.8	* 1.29E-02	(8.99E-03)	[PNL]	9.18E-04	(8.55E-05)	[PNL]
37.8	*-2.18E-03	(1.02E-02)	[PNL]	7.43E-04	(7.39E-05)	[PNL]
39.6	* 1.90E-02	(9.98E-03)	[PNL]	2.79E-04	(4.95E-05)	[PNL]
39.6	* 3.11E-03	(1.01E-02)	[PNL]	2.49E-04	(5.50E-05)	[PNL]

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APPENDIX B
DRILL LOGS AND CONCENTRATION PROFILES

Appendix B contains a compilation of geologic and actinide distribution data available for 42 wells drilled through or in the vicinity of the 216-Z-1A Crib. The identification number of each well, the month and year it was drilled, and its depth are listed in Table B-1. The locations of the 42 wells are shown in Plate 1. The data available for individual wells are presented in Plates 2 through 26.

Sieve data, obtained by granulometric analysis (see page 26), is presented for 12 wells. The sediment size notation used to represent the sieve data follows the classification scheme presented in Figures 12 and 13 (within the text). Silt plus clay is indicated by 'M', sand by 'S', and gravel by 'G'. The major component of a sediment is indicated by the last letter in the notation and preceeding letters, if present, are modifiers indicating additional components. Thus 'GS' indicates a 'gravelly sand' while 'SG' indicates a 'sandy gravel'. The major classification of sand is subdivided according to the scheme given in Figure 12. The subdivisions are indicated by a notation within a bracket which modifies the sand, where VC = very coarse, C = coarse, M = medium, F = fine, and VF = very fine. Thus, (M)G[F - VF]S would indicate a 'slightly silty, gravelly, fine to very fine sand'.

Drill log data is listed for all 43 wells. These logs were compiled by a driller and/or by a geologist during well emplacement. The description and size classification of sediments are qualitative, as opposed to the quantitative sieve data.

Sediment descriptions recorded in the drill log, supplemented by available granulometric data, are graphically summarized by a lithologic log. The symbols used to construct these logs are identified as follows:

Gravel

TABLE B-1

WELLS DRILLED THROUGH AND IN THE VICINITY OF THE 216-Z-1A CRIB

WELL NUMBER	DATE DRILLED	DEPTH DRILLED (METERS)
299-W18-6	1/64	91.5
W18-7	1/64	91.5
W18-56	3/49	45.7
W18-57	3/49	45.7
W18-58	3/49	45.7
W18-59	3/49	45.7
W18-60	4/49	45.7
W18-61	4/49	45.7
W18-62	4/49	45.7
W18-63	4/49	45.7
W18-64	4/49	45.7
W18-65	4/49	45.7
W18-66	4/49	45.7
W18-67	9/49	14.3
W18-68	9/49	14.0
W18-76	3/67	5.8
W18-77	3/67	7.6
W18-78	3/67	5.2
W18-79	3/67	7.0
W18-80	3/67	6.4
W18-81	4/67	12.5
W18-85	8/69	45.7
W18-86	8/69	45.7
W18-87	9/69	45.7
W18-88	9/69	45.7
W18-89	10/69	45.7
W18-149	1/74	29.0

TABLE B-1 (Cont.)

WELL NUMBER	DATE DRILLED	DEPTH DRILLED (METERS)
299-W18-150	6/74	39.0
W18-158	9/76	40.0
W18-159	12/77	39.6
W18-163	2/77	41.2
W18-164	1/77	46.6
W18-165	2/77	41.2
W18-166	4/77	41.8
W18-167	4/77	40.9
W18-168	6/77	39.9
W18-169	6/77	40.2
W18-171	7/77	41.5
W18-172	8/77	40.9
W18-173	10/77	15.2
W18-174	10/77	15.2
W18-175	11/77	39.6


Sand


Silt


Caliche Flakes, Fragments or Stringers


Caliche

The relative density of individual patterns indicates the relative abundance of the various sediment size classes (Figure 12).

Concentration profiles were constructed for the purpose of rapid comparisons of radionuclide concentrations with lithology. Profiles for the 15 characterization wells drilled since 1973 are presented in Plates 11 through 26. To derive these profiles, $^{239,240}Pu$ and ^{241}Am values reported in Appendix A were plotted beside the lithologic log for each well. The bulk of the analytical data plotted was analyzed by PNL. Hence, a value of 10^{-2} nCi/g was selected for the X-axis because this concentration approximates PNL's lowest limit of detection for plutonium (2.7×10^{-2} nCi/g for a 100-minute count).

Two symbols, a solid and an open circle, were selected to represent analytical results. A solid circle indicates a "real" value and an open circle indicates a "less than" value as defined in Appendix A. Plutonium and americium concentrations less than 10^{-2} nCi/g were plotted on the Y-axis to indicate sample position.

As presented in Appendix A, a separate aliquot of the same sample may have been analyzed by one to three laboratories. When more than one laboratory analysis was available for a sample, the results reported by the laboratory with the lowest limit of detection were plotted. The order of laboratory preference is as follows: LFE, PNL, IRT, and Rockwell. Although PNL and IRT have similar limits of detection, a considerably

greater number of samples were analyzed by PNL; therefore, PNL analyses were preferred over IRT analyses.

Zones of contamination detected by portable radiation survey instruments (see Glossary) were recorded in the drill log. These field survey results are shown by a solid vertical bar located between the plutonium and americium concentration profiles. The bars indicate portions of the sediment column where activity greater than 2.3×10^{-1} nCi (at the surface of a 100 square-centimeter detector) is present.

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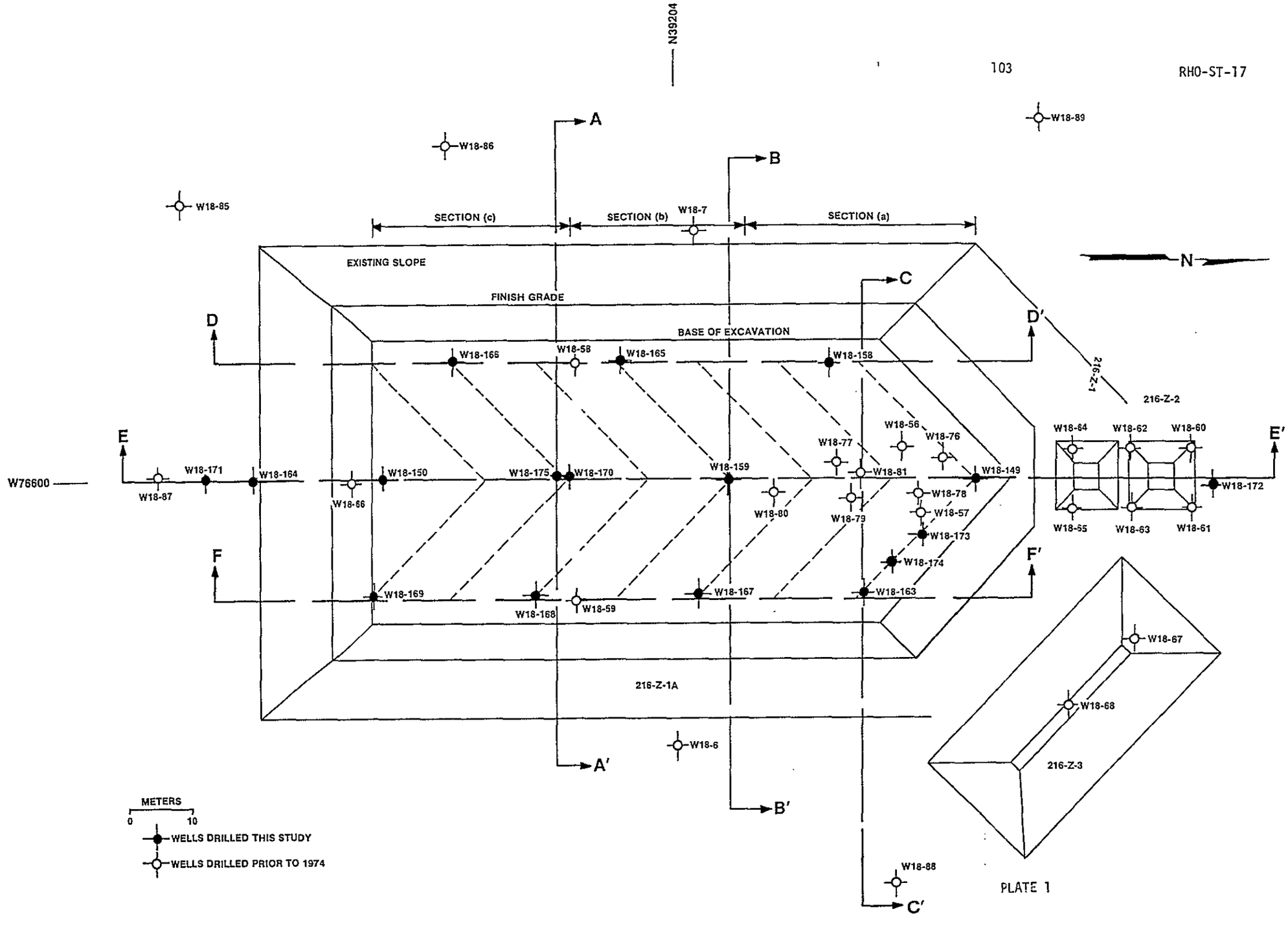
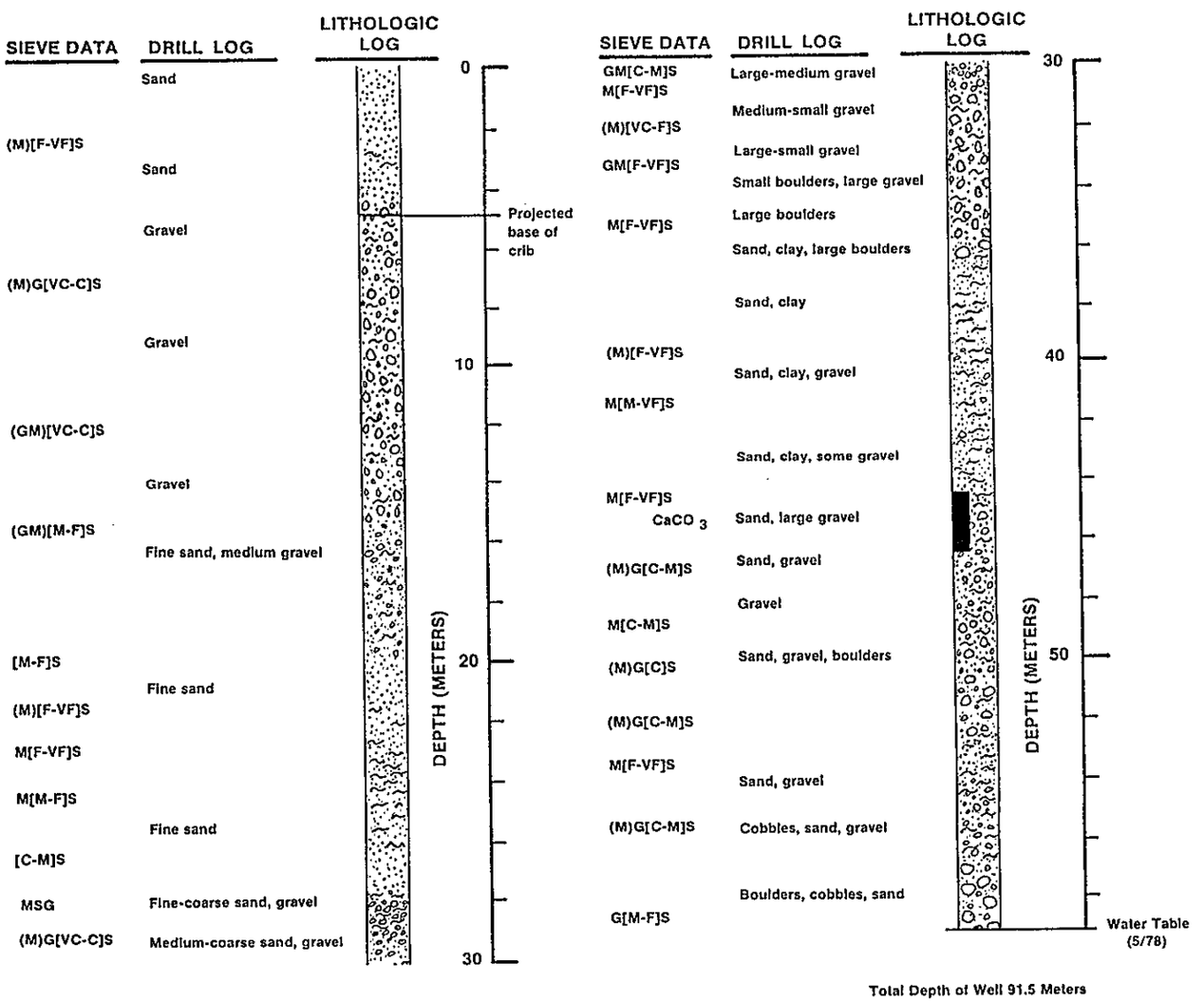

N39204
W18-86
W18-89
W18-85
A
B
SECTION (c)
SECTION (b)
W18-7
SECTION (a)
EXISTING SLOPE
FINISH GRADE
BASE OF EXCAVATION
C
D
D'
N
W18-166
W18-58
W18-165
W18-158
216-Z-1
216-Z-2
E
E'
W76600
W18-171
W18-164
W18-87
W18-66
W18-150
W18-175
W18-170
W18-159
W18-80
W18-77
W18-56
W18-76
W18-81
W18-149
W18-79
W18-78
W18-57
W18-173
W18-174
W18-64
W18-62
W18-60
W18-172
W18-65
W18-63
W18-61
F
F'
W18-169
W18-168
W18-59
W18-167
W18-163
W18-67
W18-68
216-Z-1A
216-Z-3
W18-6
A'
B'
C'
W18-88
METERS
0
10
WELLS DRILLED THIS STUDY
WELLS DRILLED PRIOR TO 1974

PLATE 1

WELL 299-W18-6

ELEVATION (METERS ABOVE MSL): 206.8



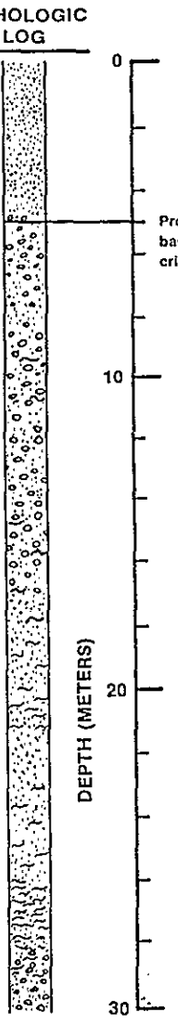
Total Depth of Well 91.5 Meters

PLATE 2

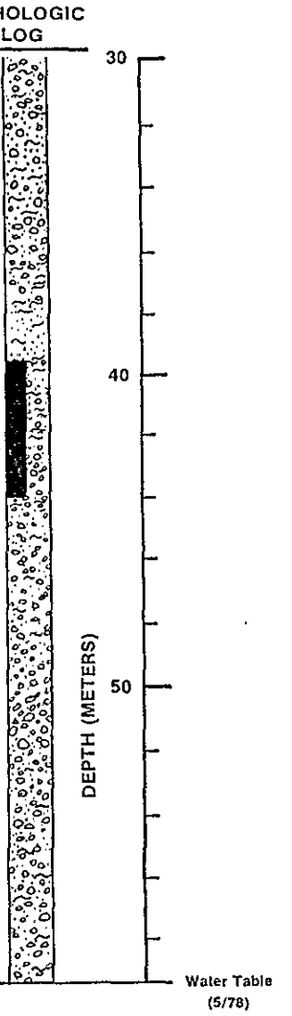
WELL 299-W18-7

ELEVATION (METERS ABOVE MSL): 207.0

SIEVE DATA	DRILL LOG
(GM)[VC-M]S	Fine sand
(GM)[VC-M]S	1/2" gravel, fine sand
SG	
G[VC-C]S	Coarse sand, small gravel
(M)G[VC-C]S	Small gravel, fine sand
MSG	1/2" gravel, fine sand
SG	
SG	
MSG	1/2" gravel, fine sand
MSG	
(M)[F-VF]S	Brown sand
M[F-VF]S	
[M-F]S	
M[M-VF]S	Brown sand
(M)[M-F]S	Brown sand, some clay
SM	
MSG	Brown sand, gravel
MSG	1/4" gravel, fine sand
MSG	1/2" gravel, fine sand



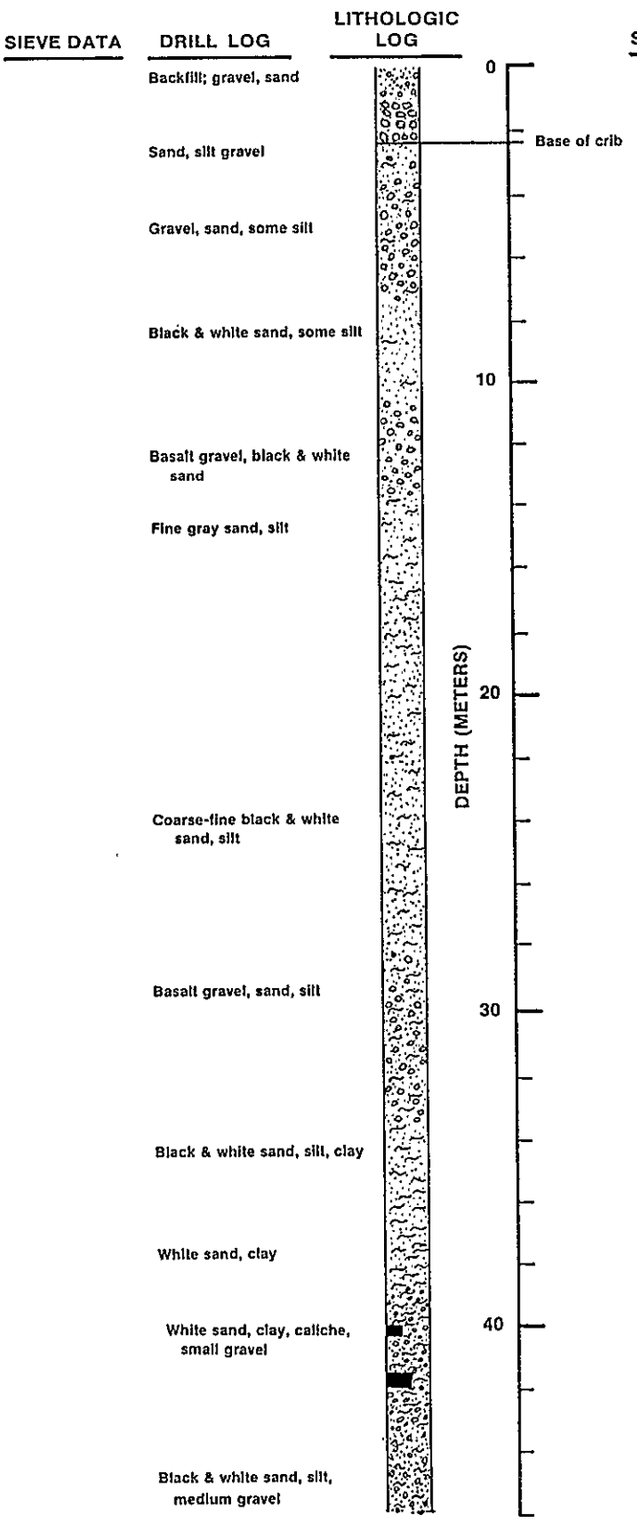
SIEVE DATA	DRILL LOG
MSG	1/2" gravel, fine sand
MSG	Gravel
MSG	Fine sand, large gravel
MSG	Gravel, brown sand, some clay
(G)SM	Clay, Some clay, brown sand
GSM $CaCO_3$	Clay, some sand, gravel
	Gravel
GM[F-VF]S $CaCO_3$	Clay, sand, gravel Gravel, brown sand, some clay
MSG $CaCO_3$	Gravel, sand, clay
GM[VC-C]S	1/2" gravel, sand, some clay
	1/2" gravel, sand, some clay
MSG	1/2" gravel, brown sand
MSG	Gravel, brown sand
SG	Gravel, sand
(M)G[C-M]S	Gravel, brown sand
(M)G[M-F]S	Gravel, brown sand
MSG	
MSG	1/2" gravel, brown sand



Total Depth of Well 91.5 Meters

WELL 299-W18-56

ELEVATION (METERS ABOVE MSL): 204.4



WELL 299-W18-57

ELEVATION (METERS ABOVE MSL): 204.5

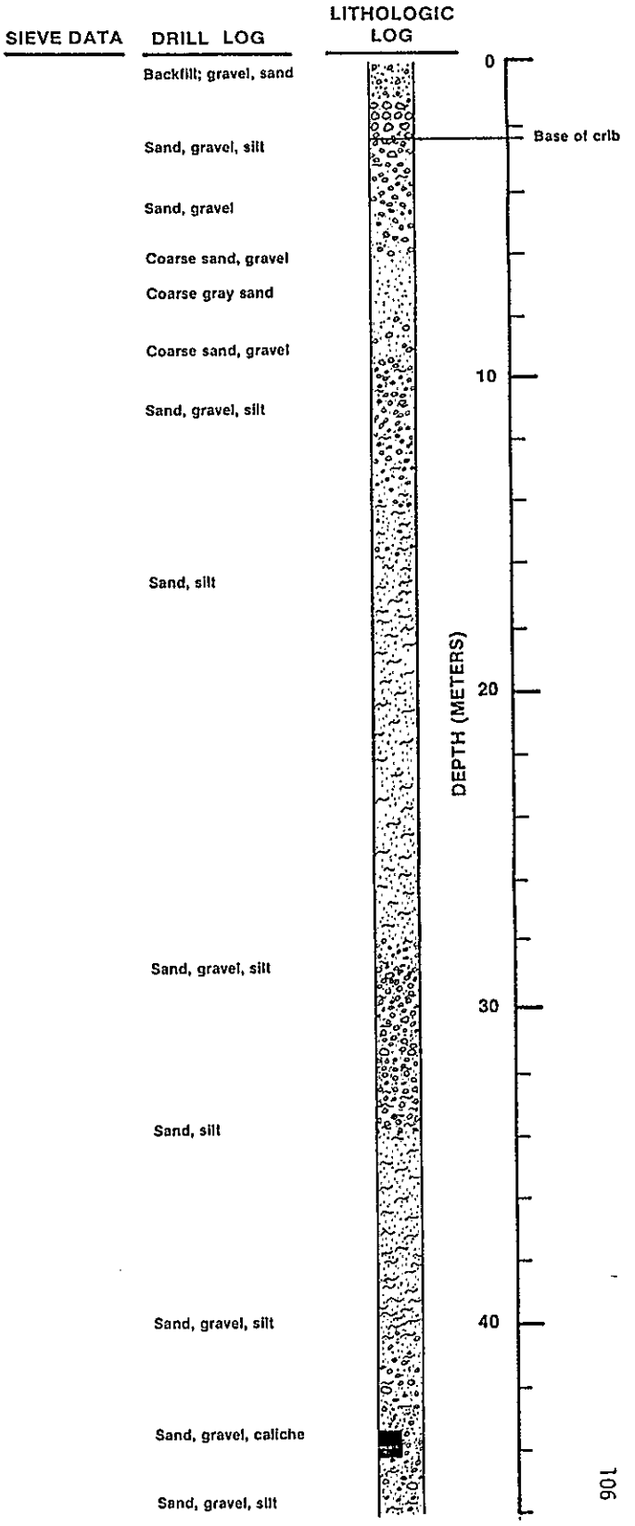
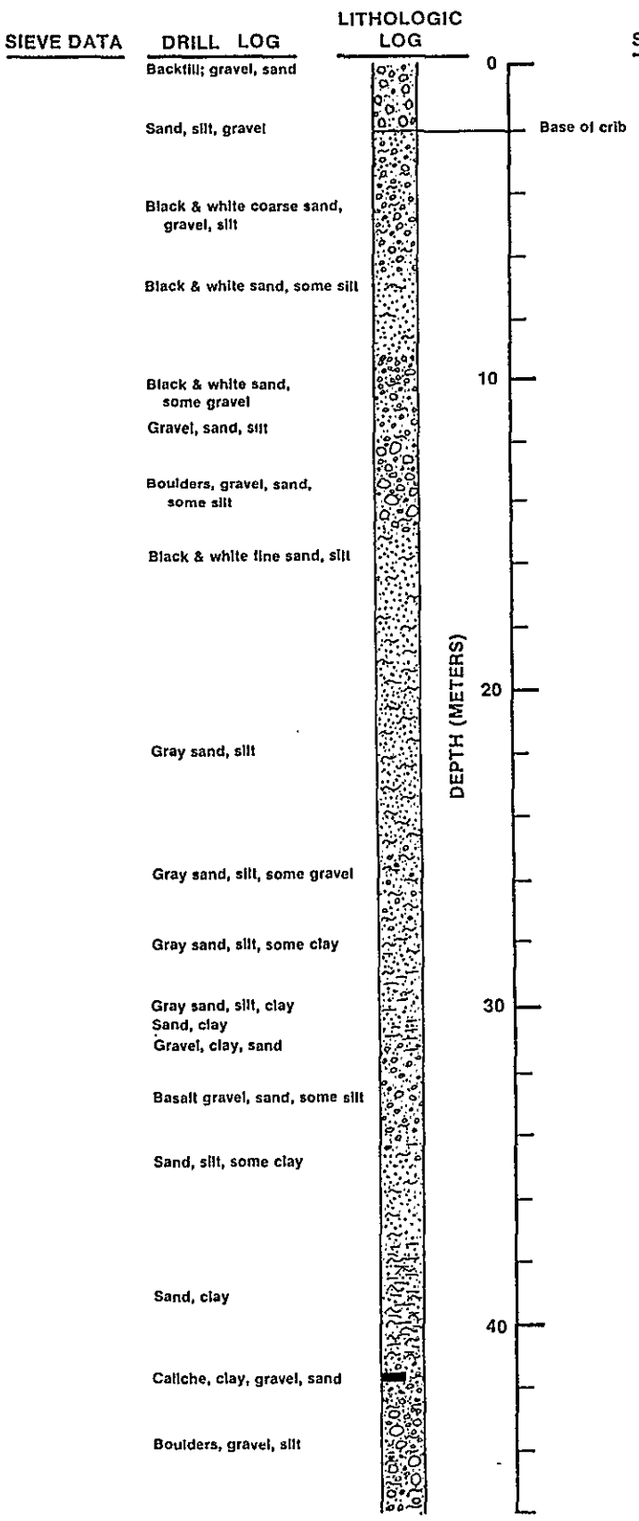


PLATE 4

WELL 299-W18-58

ELEVATION (METERS ABOVE MSL): 203.6



WELL 299-W18-59

ELEVATION (METERS ABOVE MSL): 204.2

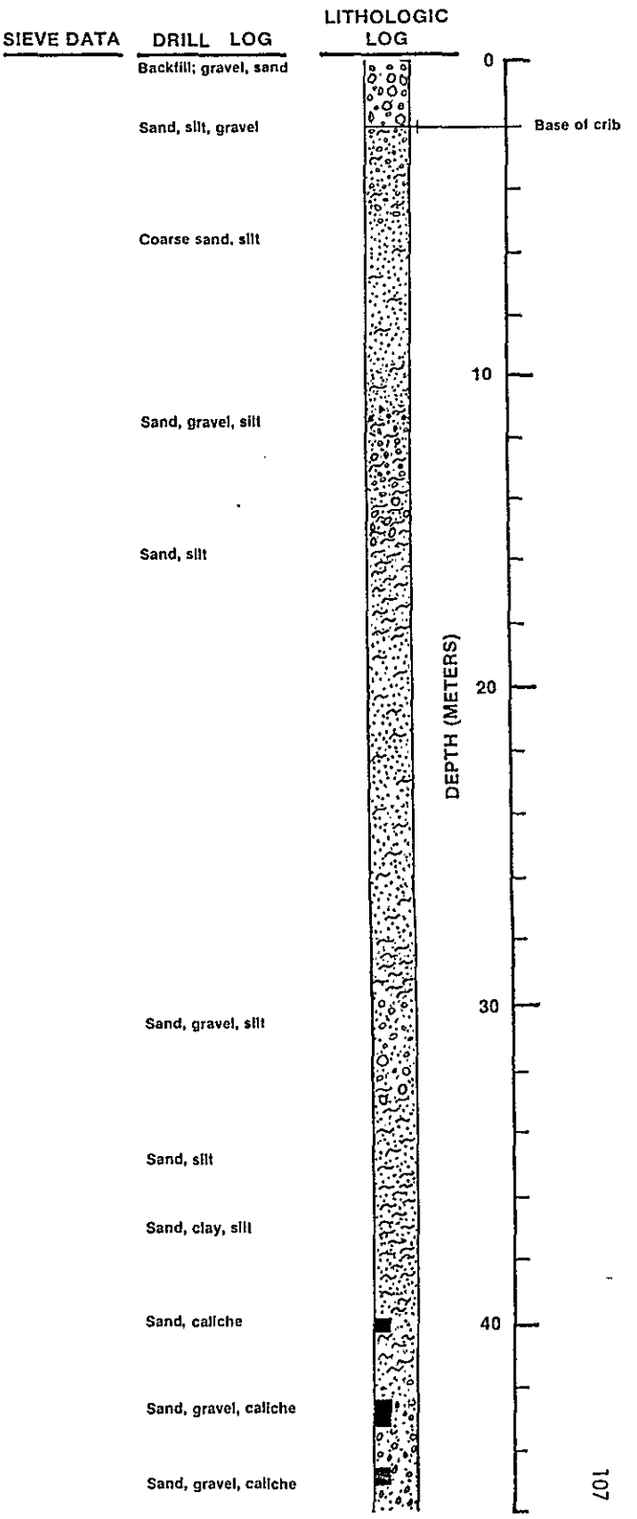


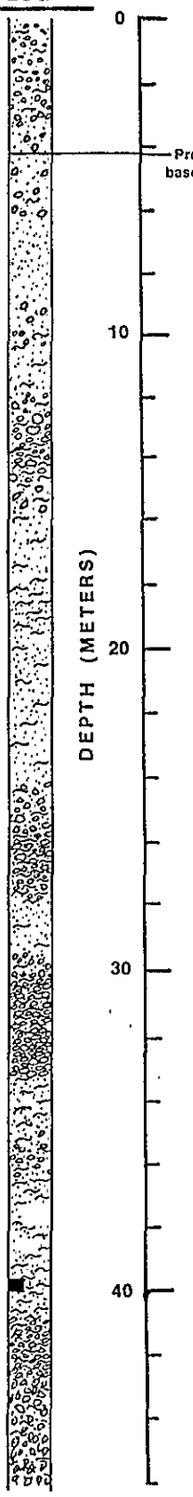
PLATE 5

WELL 299-W18-61

ELEVATION (METERS ABOVE MSL): 206.3

SIEVE DATA	DRILL LOG
(M)G[F-VF]S	Sand, silt
(M)G[F-VF]S	Sand, silt
[C-M]S	
[C-M]S	Sand, silt, gravel
(M)[M-VF]S	
(M)G[VC-C]S	Sand, gravel, silt, boulders
GM[VC-C]S	
(M)[F-VF]S	Sand, gravel, silt
(M)[M-F]S	
M[F-VF]S	Sand, silt
(M)[M-F]S	
(M)[F-VF]S	Sand, silt, clay
(M)[M-F]S	
(M)G[M-F]S	Sand, gravel, silt, clay
MSG	
(M)[C-M]S	Sand,gravel, silt
(M)[VC-C]S	Sand, silt
MSG	
SG	Sand, gravel, silt
	Sand, gravel, silt, boulders
M[F-VF]S	Sand, silt
(M)G[M-F]S	
M[M-VF]S	Sand, gravel, silt
M[VF]S	Silt, clay, sand
M[VF]S	Caliche, sand, clay, gravel
MSG	Sand, silt, gravel
(M)G[C-M]S	Sand, gravel, silt
(M)G[C-M]S	
SG	Sand, gravel, silt

LITHOLOGIC LOG

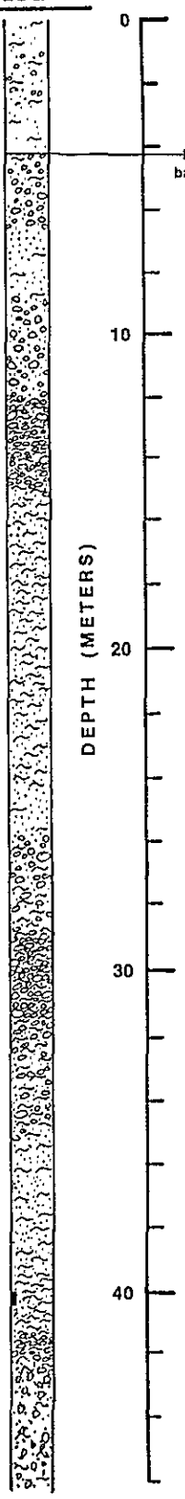


WELL 299-W18-65

ELEVATION (METERS ABOVE MSL): 206.3

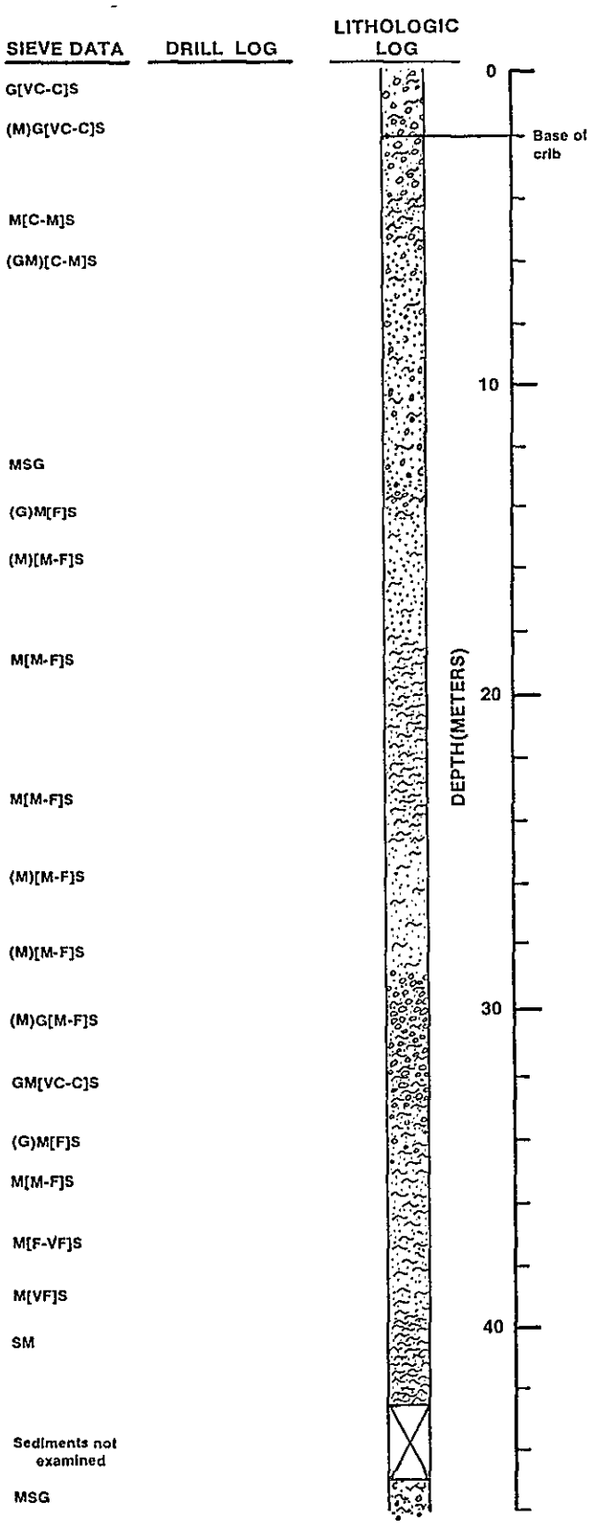
SIEVE DATA	DRILL LOG
(GM)[F-VF]S	Sand, silt
(M)[F-VF]S	Sand, silt
(M)G[F-VF]S	
G[VC-C]S	Sand, gravel, silt
(M)[VC-C]S	
G[VC-C]S	Sand, gravel, silt
MSG	
MSG	Sand, gravel, silt
M[M-VF]S	
	Silt, sand
M[F-VF]S	
M[F-VF]S	Sand, silt
M[M-F]S	
(M)G[C-F]S	Sand, gravel, silt
(G)M[VC-C]S	
MSG	
MSG	Sand, gravel, silt
GM[VC-C]S	
GM[VC-C]S	Sand, gravel, silt
	Sand, clay, silt
M[F-VF]S	
SM	Sand, clay, silt, caliche
MSG	Sand, gravel
(M)G[C-M]S	Sand, gravel
(M)G[C-M]S	Coarse sand, gravel, silt

LITHOLOGIC LOG



WELL 299-W18-66

ELEVATION (METERS ABOVE MSL): 203.9



WELL 299-W18-81

ELEVATION (METERS ABOVE MSL): 204.7

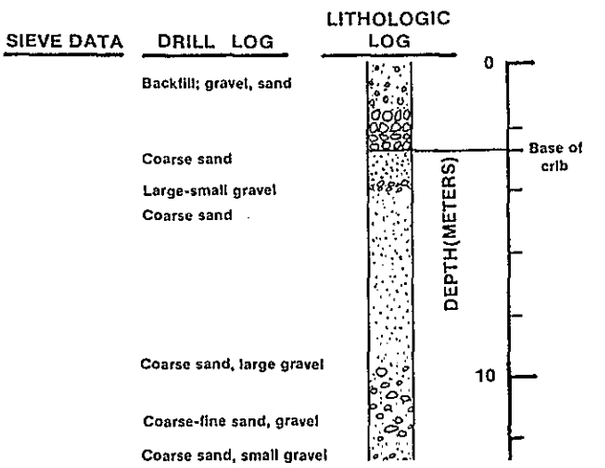
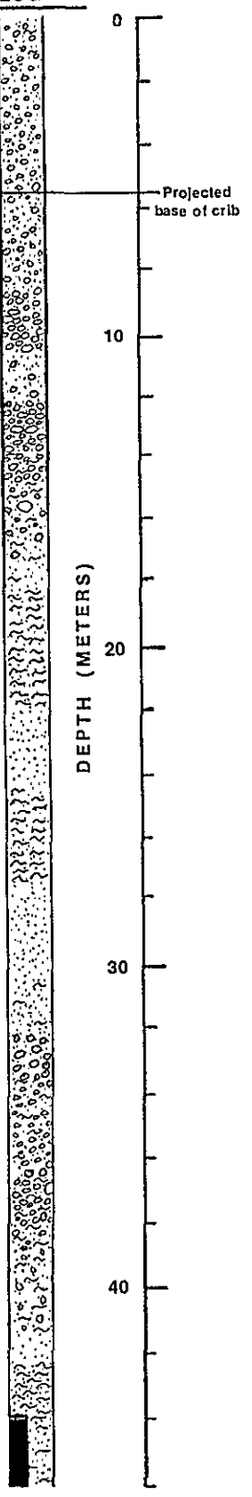


PLATE 7

WELL 299-W18-85

ELEVATION (METERS ABOVE MSL): 207.2

SIEVE DATA	DRILL LOG
GM[C-M]S	Sand, silt
G[VC-C]S	Coarse sand
G[VC-C]S	Coarse sand
(G)[VC-C]S	
G[VC-C]S	
SG	Coarse sand, small gravel
[VC-C]S	
SG	Sand, silt, 4" gravel
MSG	
GM[F-VF]S	Boulder
(M)[M-F]S	Sand, silt
M[M-VF]S	Sand, silt
[M-F]S	Sand, silt
[M-F]S	Sand, silt
M[F-VF]S	
M[M-F]S	
[M-F]S	Sand, silt
(M)[F-VF]S	
SG	Sand, silt, 2" gravel
(M)G[VC-C]S	Sand, silt, 4" gravel
MSG	3" gravel
GM[M-VF]S	
(G)SM	
SM	
M[F-VF]S $CaCO_3$	
M[F-VF]S $CaCO_3$	Caliche



WELL 299-W18-86

ELEVATION (METERS ABOVE MSL): 208.3

SIEVE DATA	DRILL LOG
G[VC-C]S	Coarse sand, silt
(M)[F-VF]S	Sand, silt
(M)G[VC-C]S	Sand, 2" gravel
(GM)[VC-C]S	Sand, silt
[M-F]S	
[M-F]S	
(G)[VC-C]S	Sand, silt
(M)G[VC-C]S	Large gravel
GM[VC-C]S	Sand, 5" gravel
GM[VC-M]S	Coarse sand, 2" gravel
GM[VC-F]S	
GM[M-F]S	Sand, silt
(M)[M-VF]S	
M[F-VF]S	
(M)[M-F]S	
M[F-VF]S	Sand, silt
(M)[C-M]S	
M[M-F]S	
(M)[M-VF]S	
M[F-VF]S	Sand, silt
GM[C-F]S	
MSG	Sand, silt, 3" gravel
GM[VC-M]S	
(M)G[VC-C]S	Sand, silt, 4" gravel
(G)M[VC-M]S	
GM[VC-M]S	
(G)M[VC-C]S	
SM	Brown clay
SM	
(GM)[C-M]S $CaCO_3$	Brown clay, basalt boulder

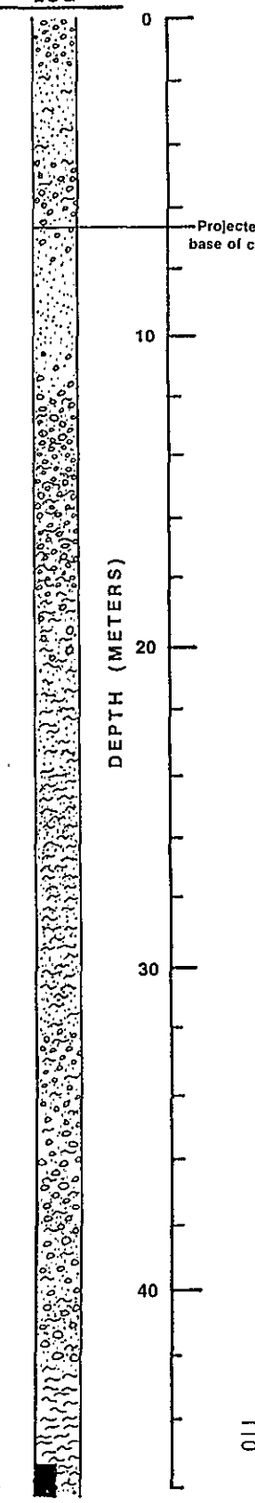


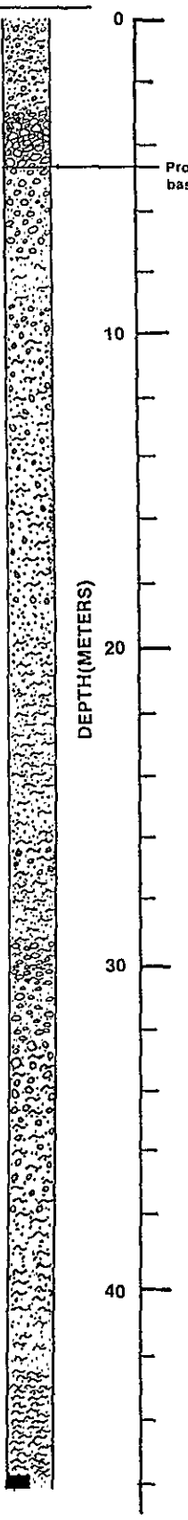
PLATE 8

WELL 299-W18-87

ELEVATION (METERS ABOVE MSL): 206.4

SIEVE DATA	DRILL LOG
(G)M[M-F]S	Sand, silt, moist
SG	Coarse sand
G[VC-C]S	
G[VC-C]S	Coarse sand, 2" gravel
(M)[F-VF]S	Fine sand
G[M-F]S	
MSG	Fine sand, 4" gravel
MSG	
SG	
MSG	
(M)G[M-F]S	Small gravel, sand, silt
[M-F]S	Sand, silt
M[F-VF]S	
	Sand, silt; moist
M[F-VF]S	Sand, silt; moist
(M)[M-F]S	
M[F-VF]S	Sand, silt; wet Large gravel
(M)[C-F]S	Sand, silt
(M)G[C-M]S	Clay, small gravel
	Sand, 3" gravel
	Small gravel
MSG	
GM[VC-M]S	
MSG	
M[F-VF]S	
M[F-VF]S	Brown clay
M[VF]S	
SM	Brown clay, sand
SM	
M[C-M]S $CaCO_3$	Caliche

LITHOLOGIC LOG



WELL 299-W18-88

ELEVATION (METERS ABOVE MSL): 207.2

SIEVE DATA	DRILL LOG
[F-VF]S	Sand, silt
[F-VF]S	
SG	25% sand, 75% gravel
G[VC-C]S	
SG	Coarse sand
SG	
G[VC-C]S	95% coarse sand, 5% gravel
G[VC-C]S	75% coarse sand, 25% gravel
SG	Sand 25%, gravel 50%, cobbles 25%
(M)[F-VF]S	
[M-F]S	Sand, gravel
(M)[F-VF]S	Sand
(M)[F-VF]S	Sand, silt
[M-F]S	Sand
(M)[M-F]S	
	Sand, silt
[C-F]S	
	Sand, gravel
MSG	
(G)M[C-M]S	
(M)[C-M]S	Sand, some gravel
[M-F]S	
(M)[F-VF]S	Sand, silt
(M)[VF]S	
[M-F]S	Sand, silt
(M)[M-F]S	
SM	
SM	Silt
MSG	Caliche
MSG $CaCO_3$	Caliche, gravel
	Caliche, 2" gravel
M[M-F]S $CaCO_3$	Sand, gravel, cobbles

LITHOLOGIC LOG

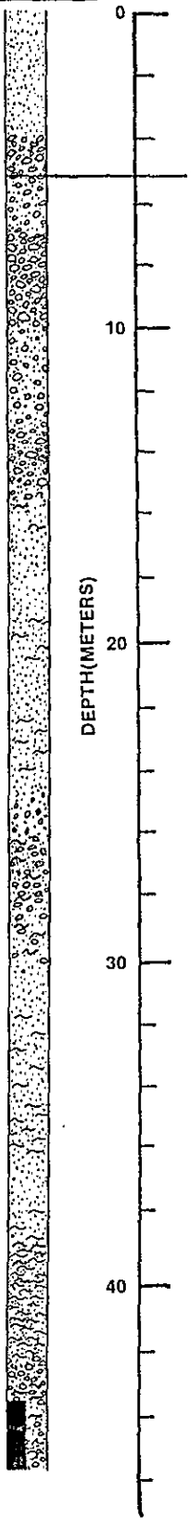
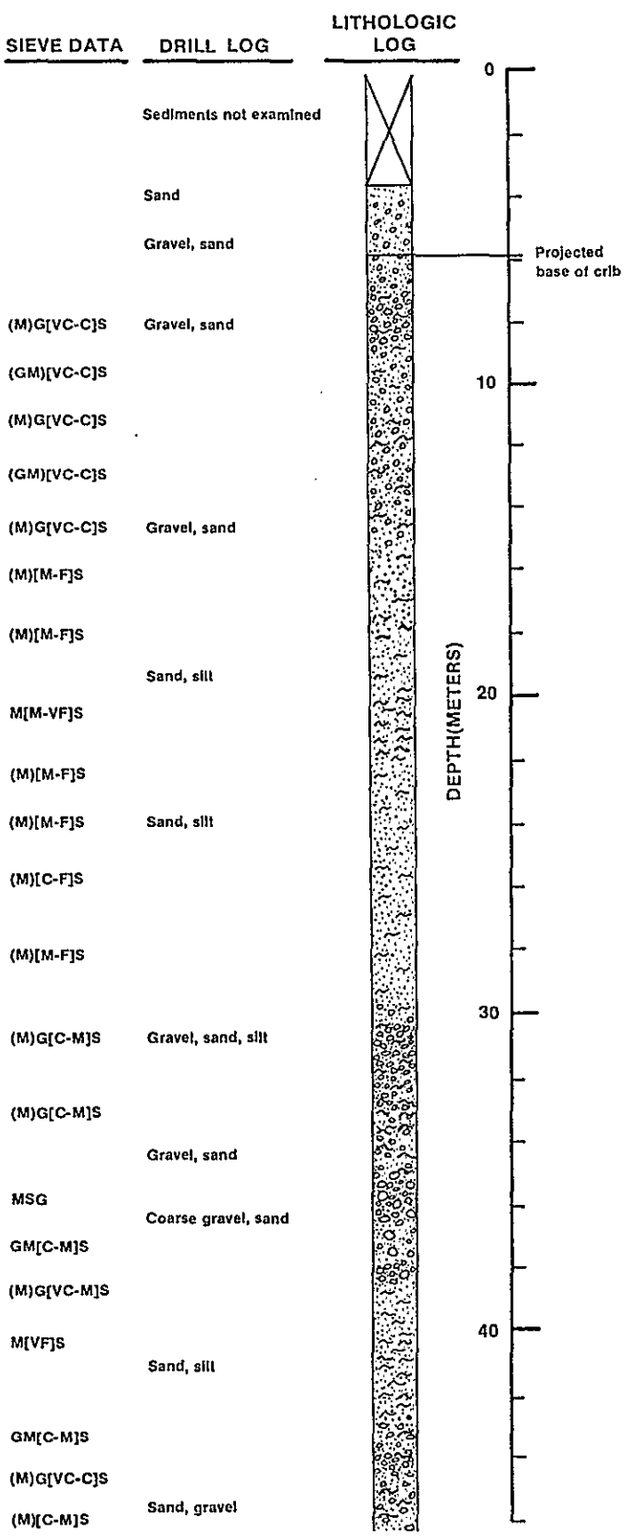


PLATE 9

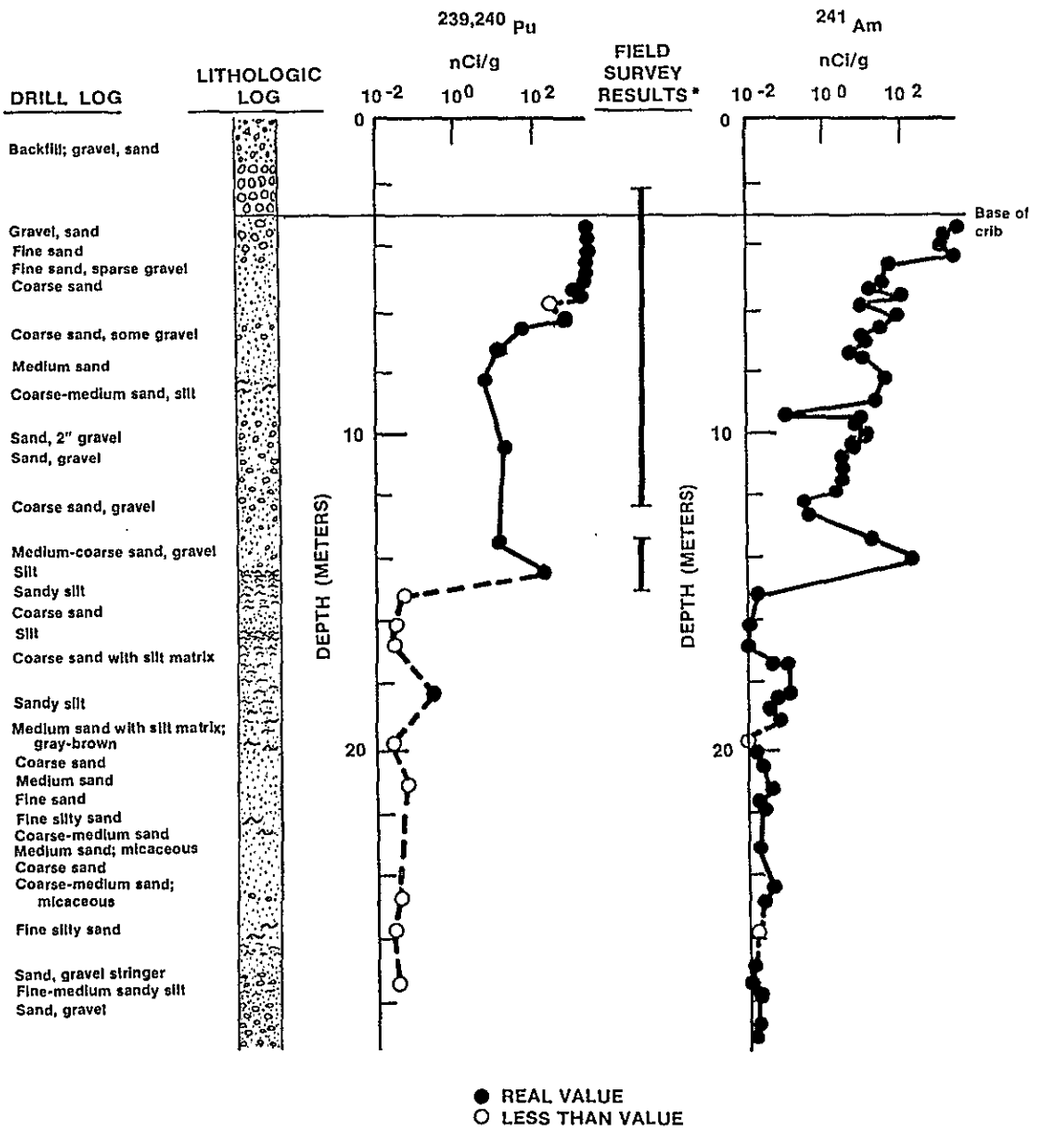
WELL 299-W18-89

ELEVATION (METERS ABOVE MSL): 207.7



WELL 299-W18-149

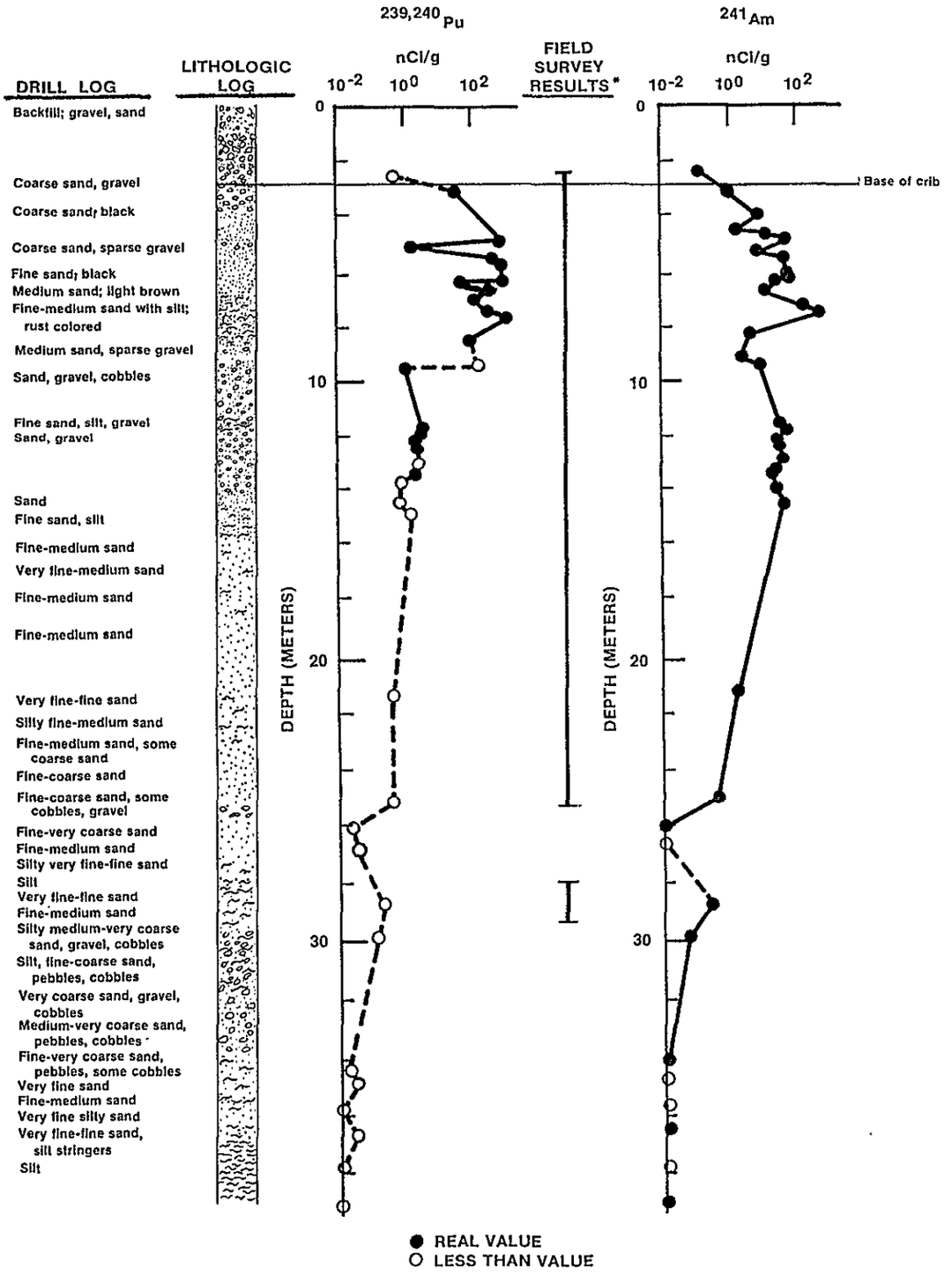
ELEVATION (METERS ABOVE MSL): 205.0



* ACTIVITY DETECTED WITH FIELD INSTRUMENTS

WELL 299-W18-150

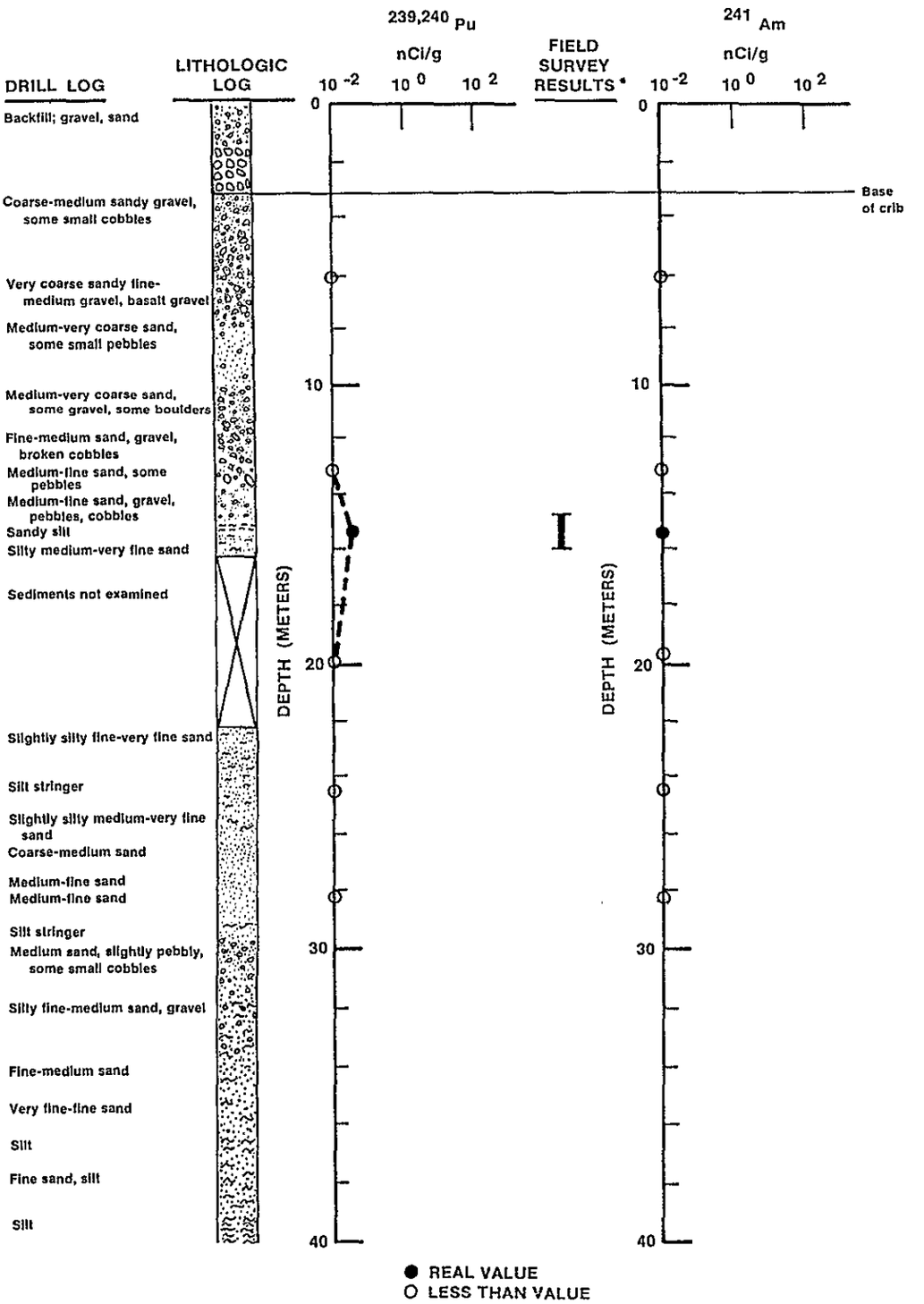
ELEVATION (METERS ABOVE MSL): 204.8



* ACTIVITY DETECTED WITH FIELD INSTRUMENTS

WELL 299-W18-158

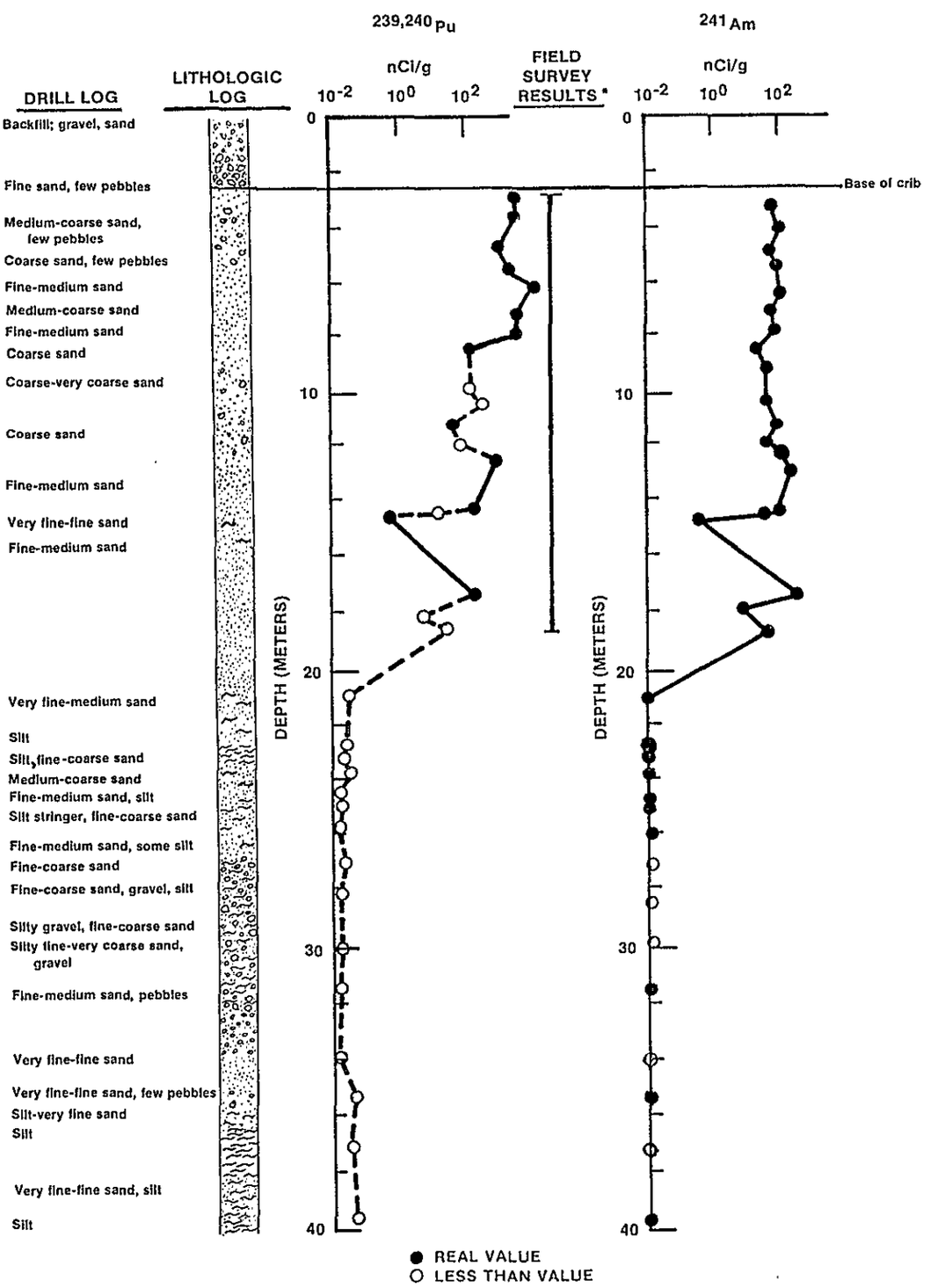
ELEVATION (METERS ABOVE MSL): 205.0



* ACTIVITY DETECTED WITH FIELD INSTRUMENTS

WELL 299-W18-159

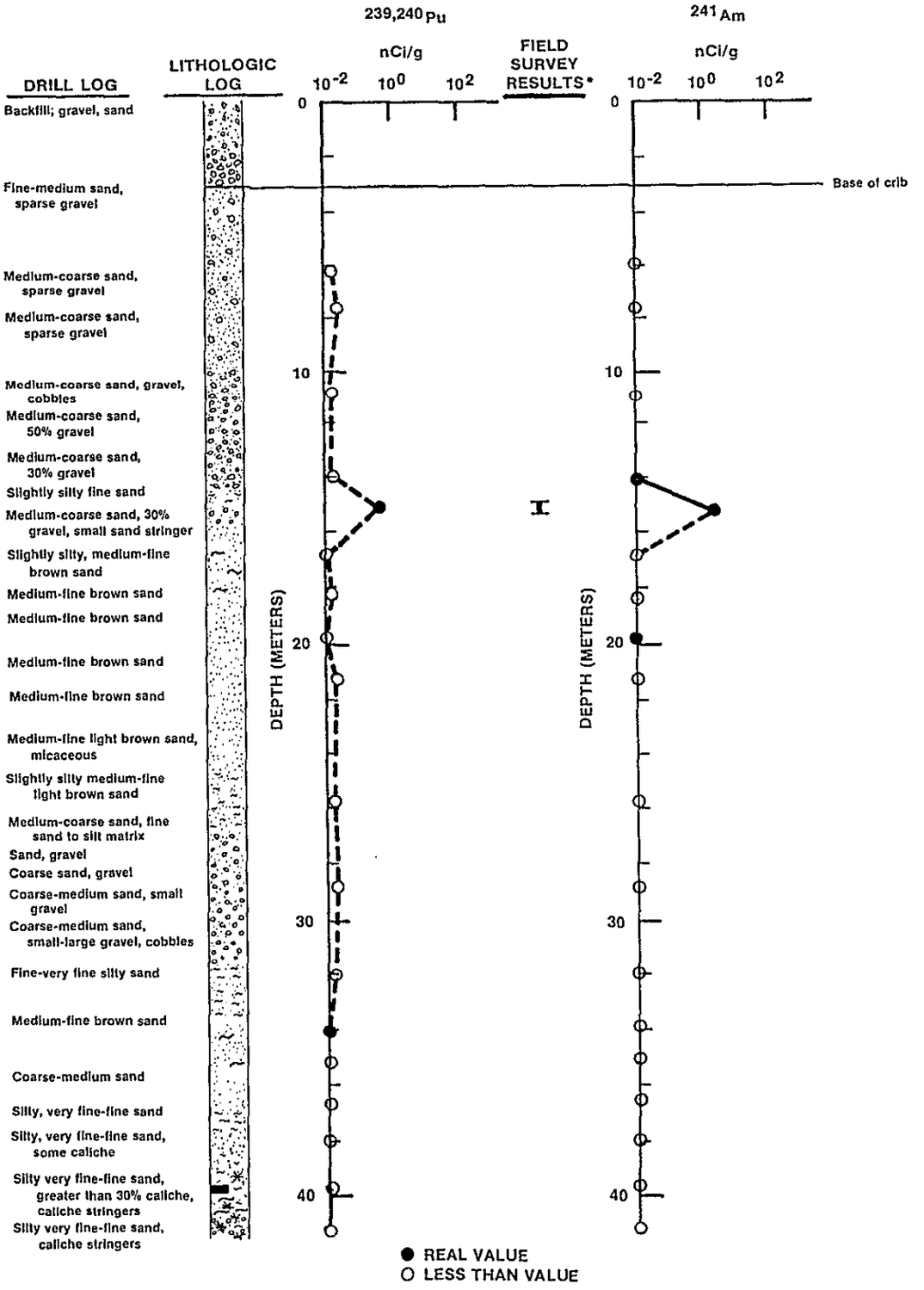
ELEVATION (METERS ABOVE MSL): 204.5



* ACTIVITY DETECTED WITH FIELD INSTRUMENTS

WELL 299-W18-163

ELEVATION (METERS ABOVE MSL): 205.1

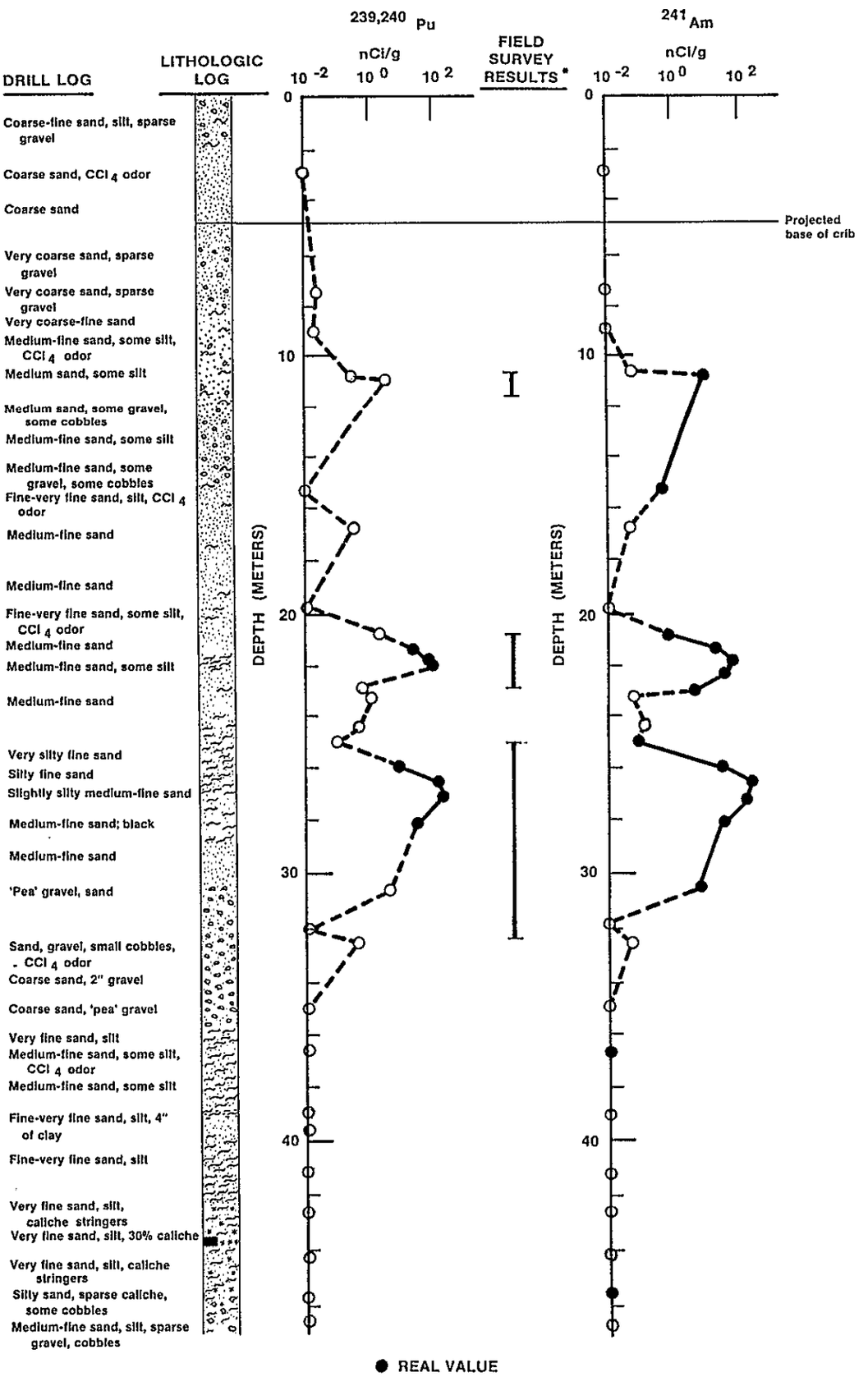


* ACTIVITY DETECTED WITH FIELD INSTRUMENTS

PLATE 15

WELL 299-W18-164

ELEVATION (METERS ABOVE MSL): 206.7



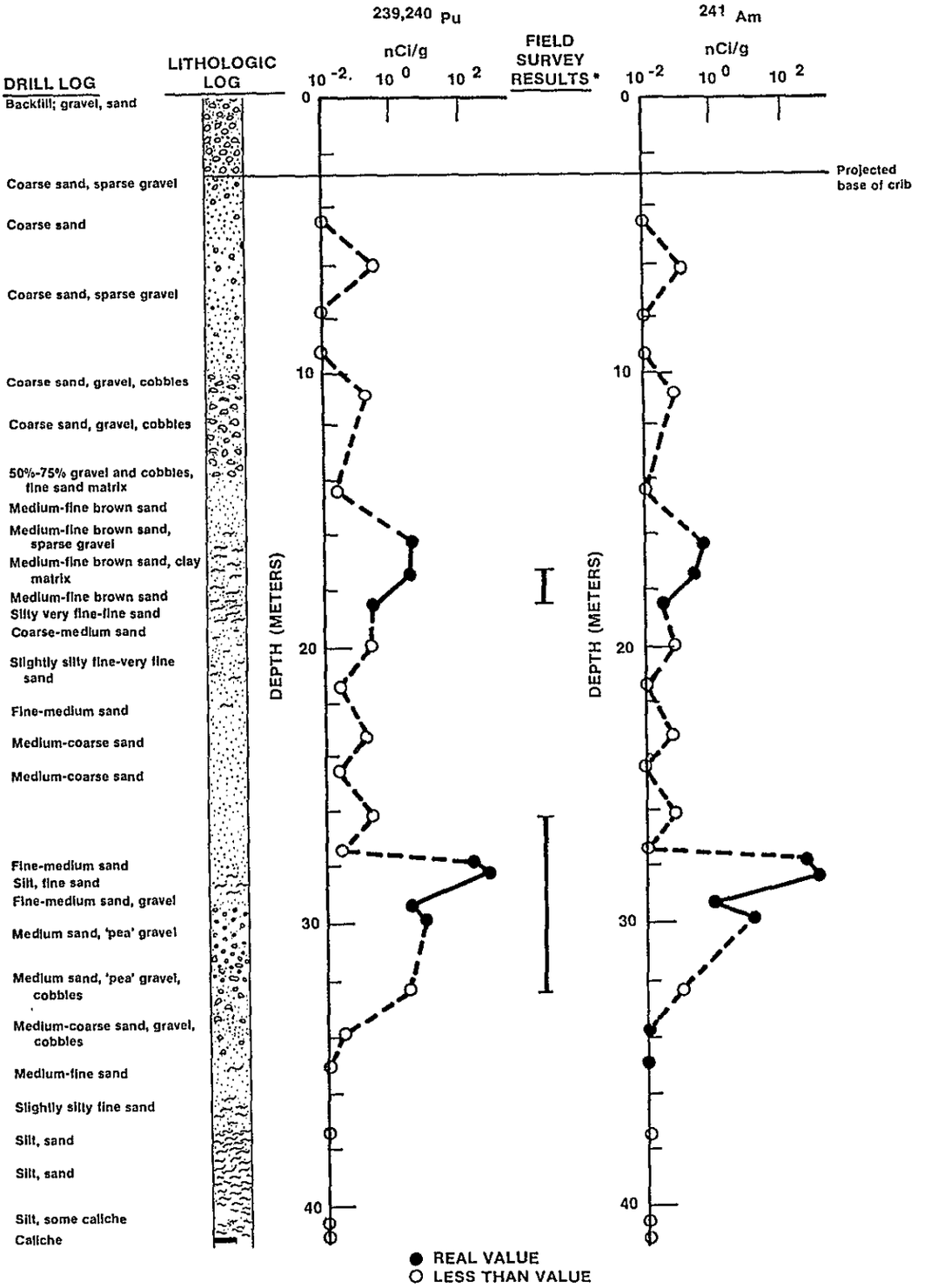
● REAL VALUE
○ LESS THAN VALUE

* ACTIVITY DETECTED WITH FIELD INSTRUMENTS

PLATE 16

WELL 299-W18-165

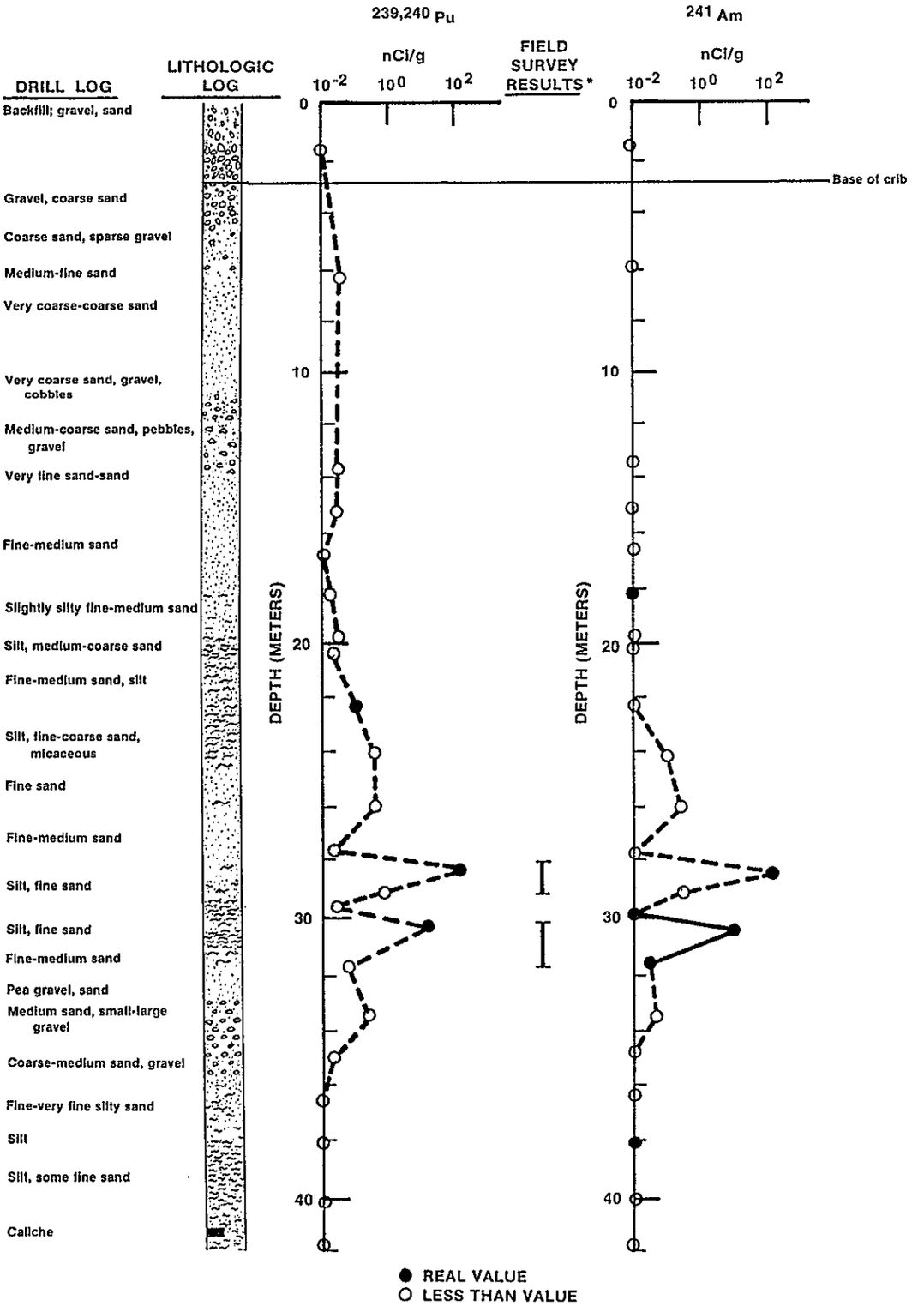
ELEVATION (METERS ABOVE MSL): 204.9



* ACTIVITY DETECTED WITH FIELD INSTRUMENTS

WELL 299-W18-166

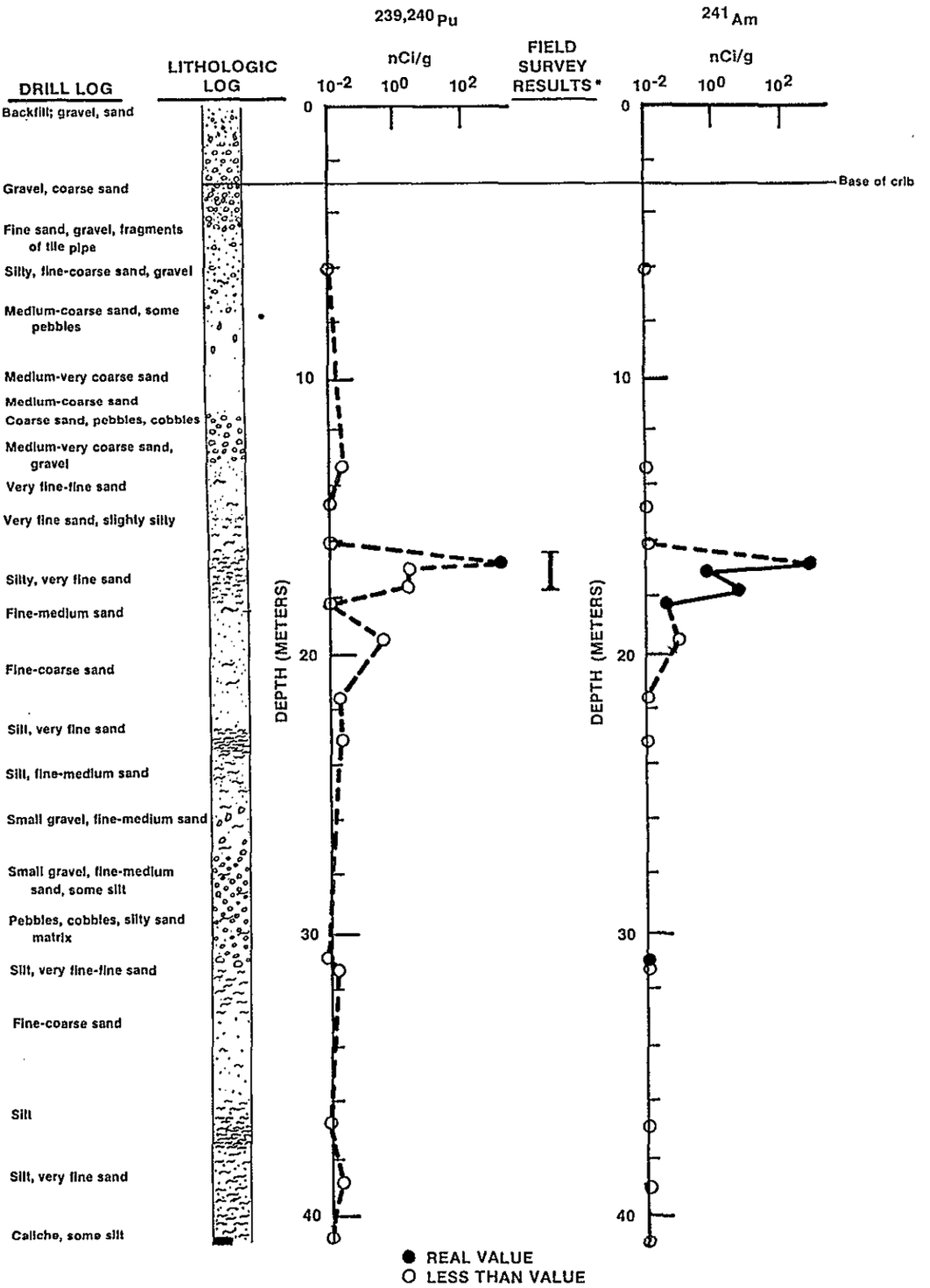
ELEVATION (METERS ABOVE MSL): 204.6



* ACTIVITY DETECTED WITH FIELD INSTRUMENTS

WELL 299-W18-167

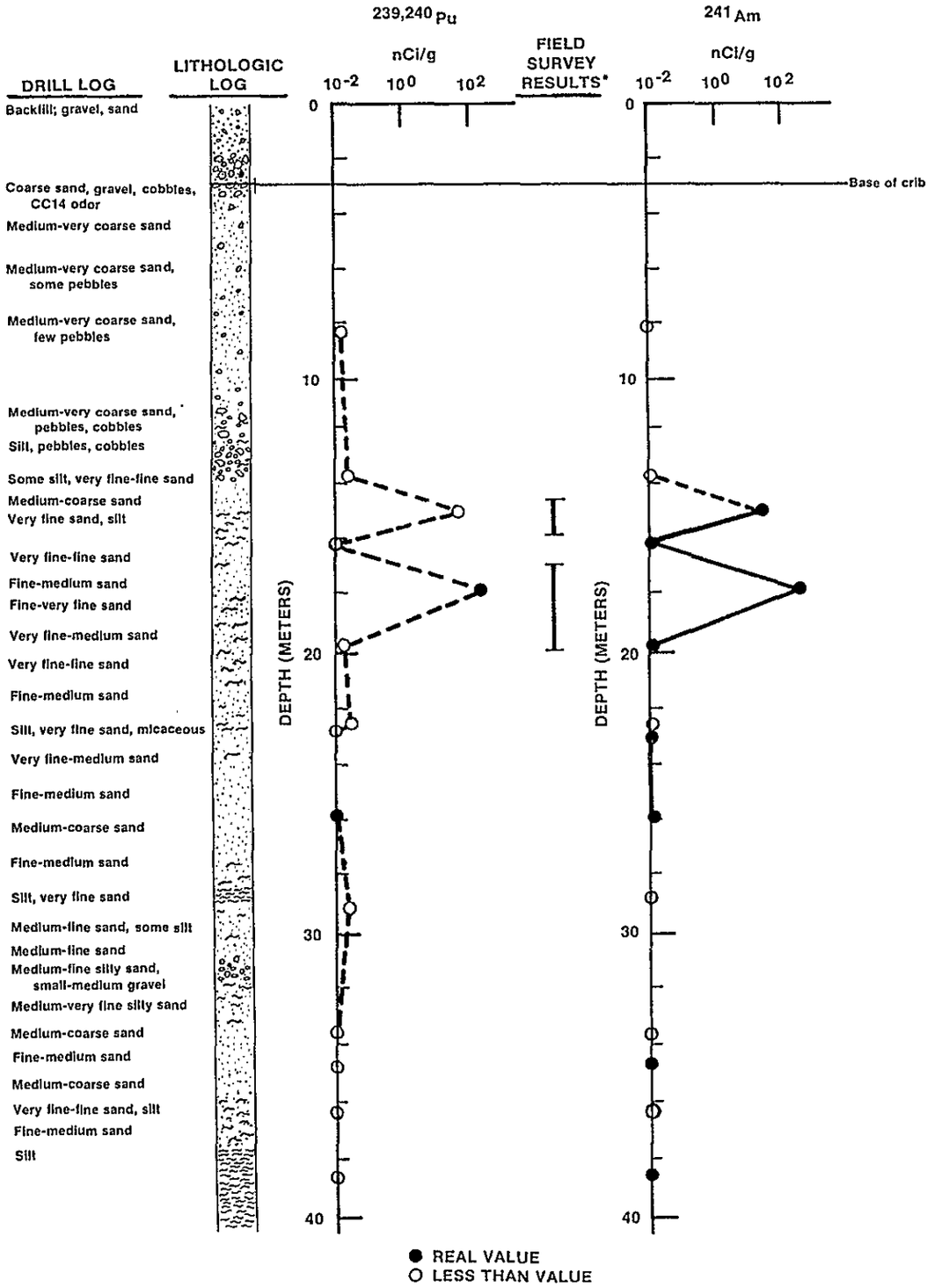
ELEVATION (METERS ABOVE MSL): 204.8



* ACTIVITY DETECTED WITH FIELD INSTRUMENTS

WELL 299-W18-168

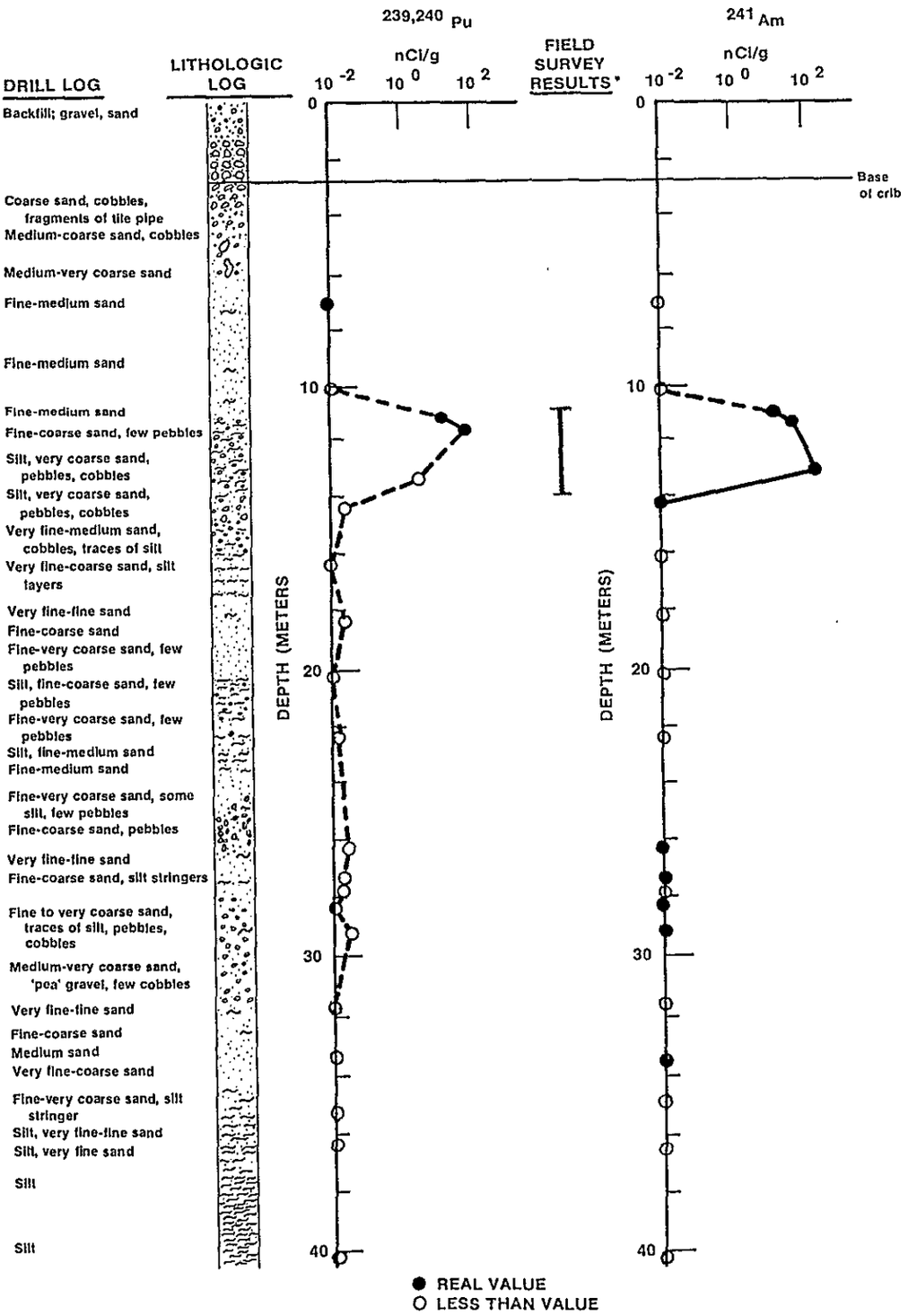
ELEVATION (METERS ABOVE MSL): 204.8



* ACTIVITY DETECTED WITH FIELD INSTRUMENTS

WELL 299-W18-169

ELEVATION (METERS ABOVE MSL): 204.9

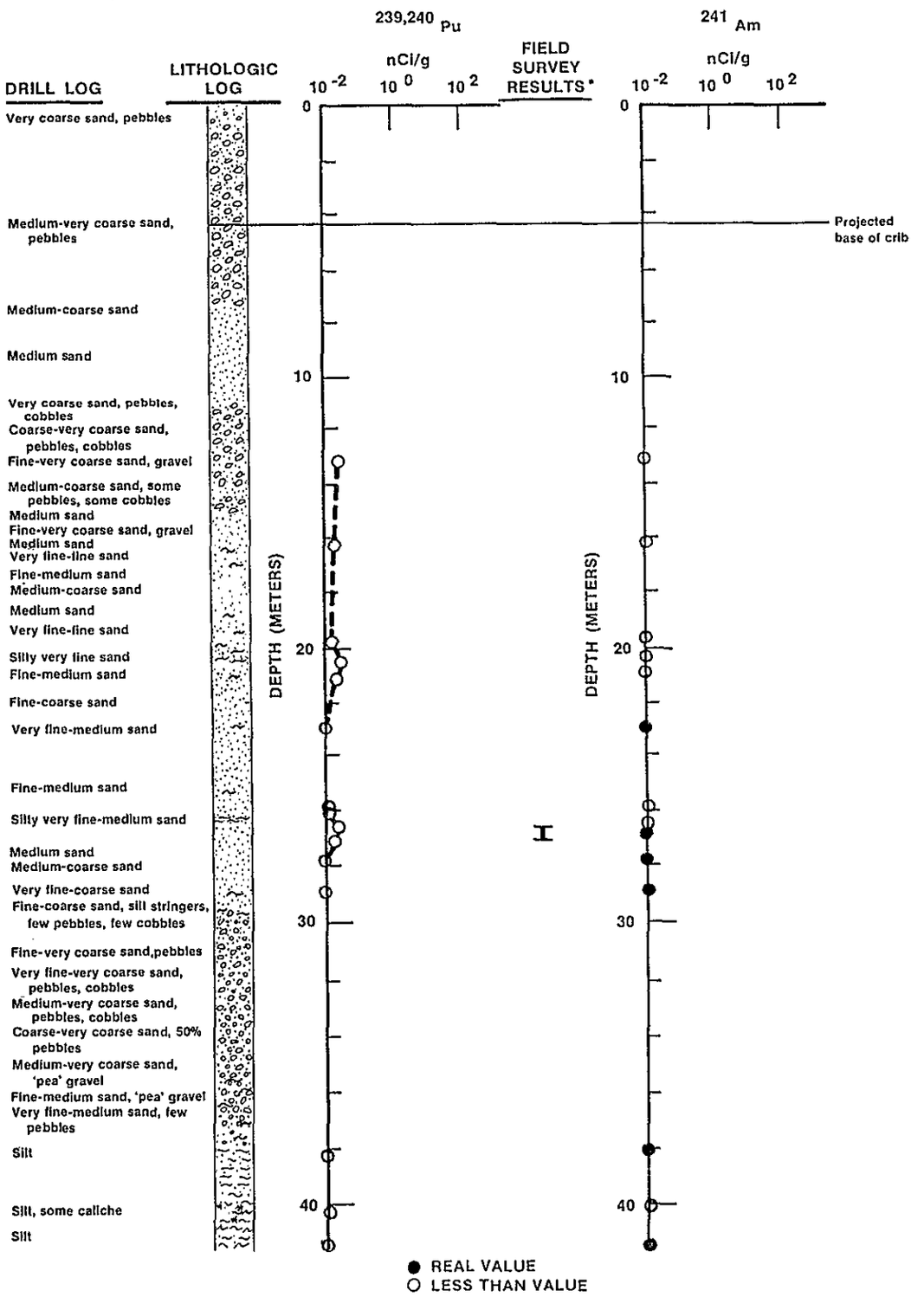


* ACTIVITY DETECTED WITH FIELD INSTRUMENTS

PLATE 21

WELL 299-W18-171

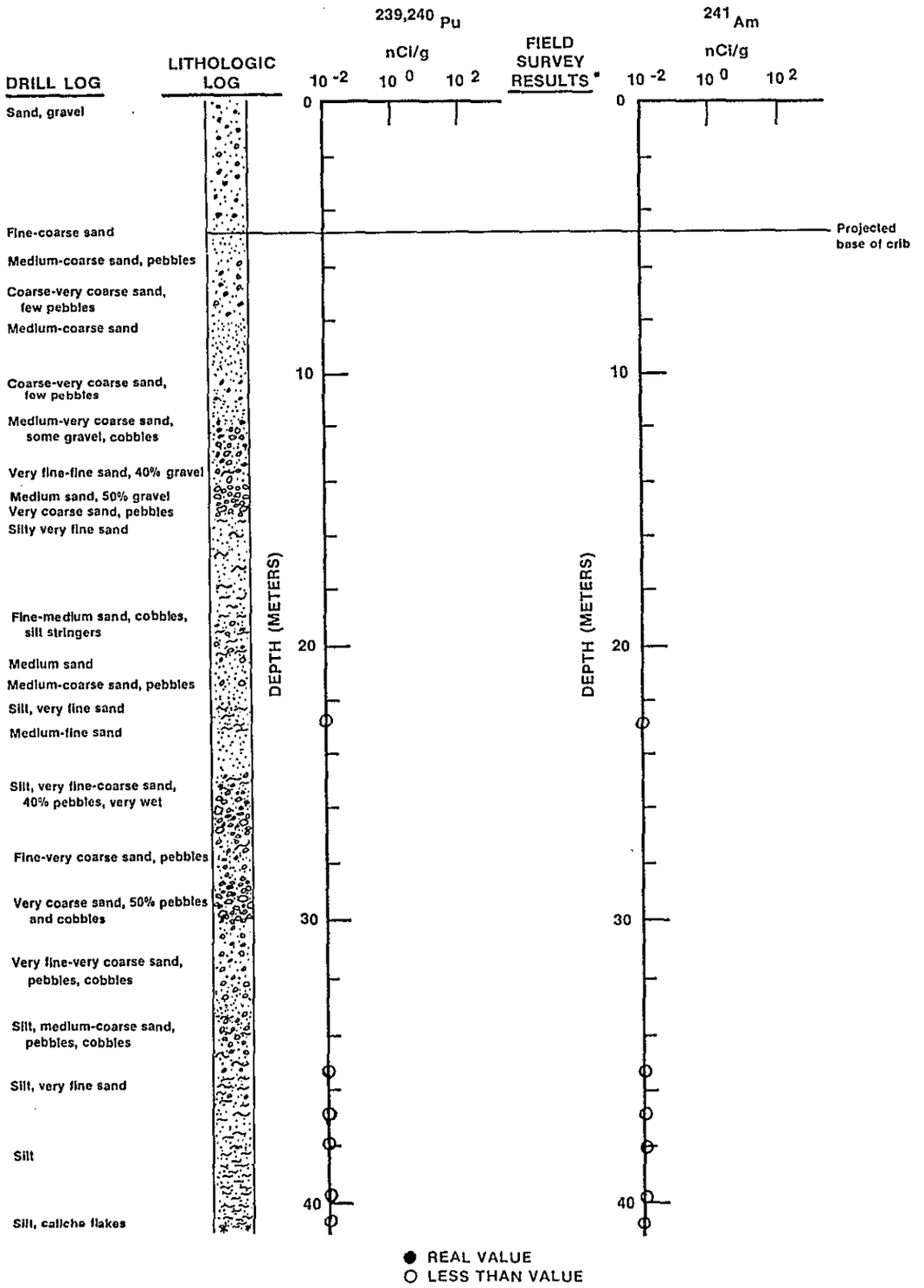
ELEVATION (METERS ABOVE MSL): 206.5



* ACTIVITY DETECTED WITH FIELD INSTRUMENTS

WELL 299-W18-172

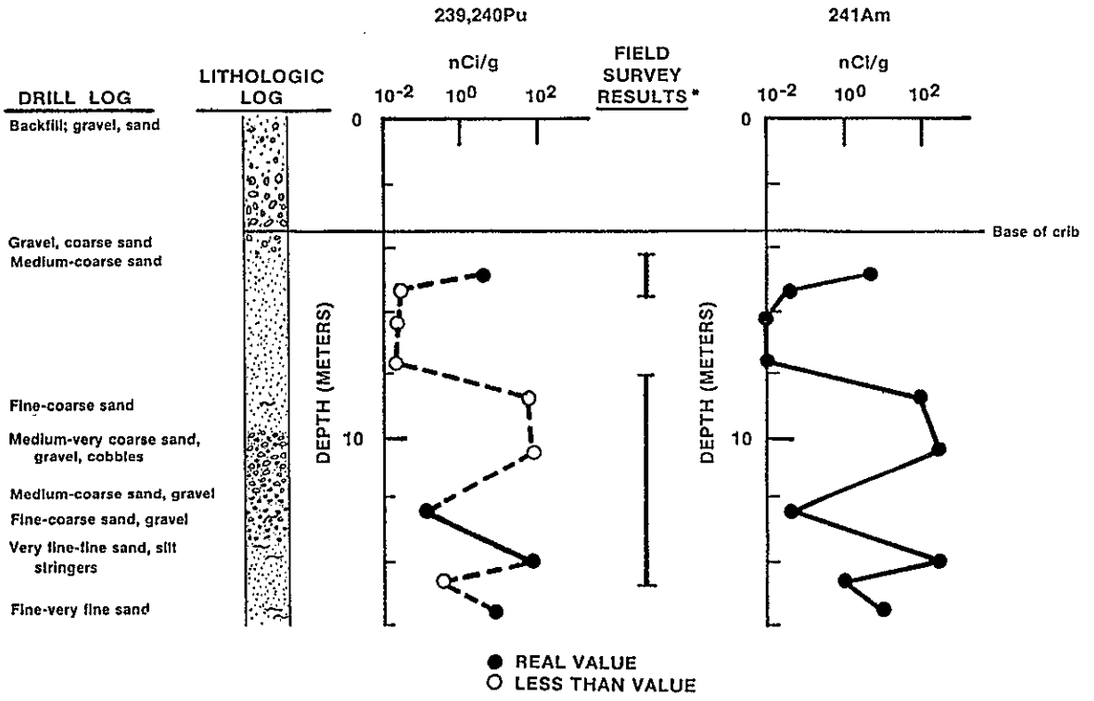
ELEVATION (METERS ABOVE MSL): 206.7



* ACTIVITY DETECTED WITH FIELD INSTRUMENTS

WELL 299-W18-173

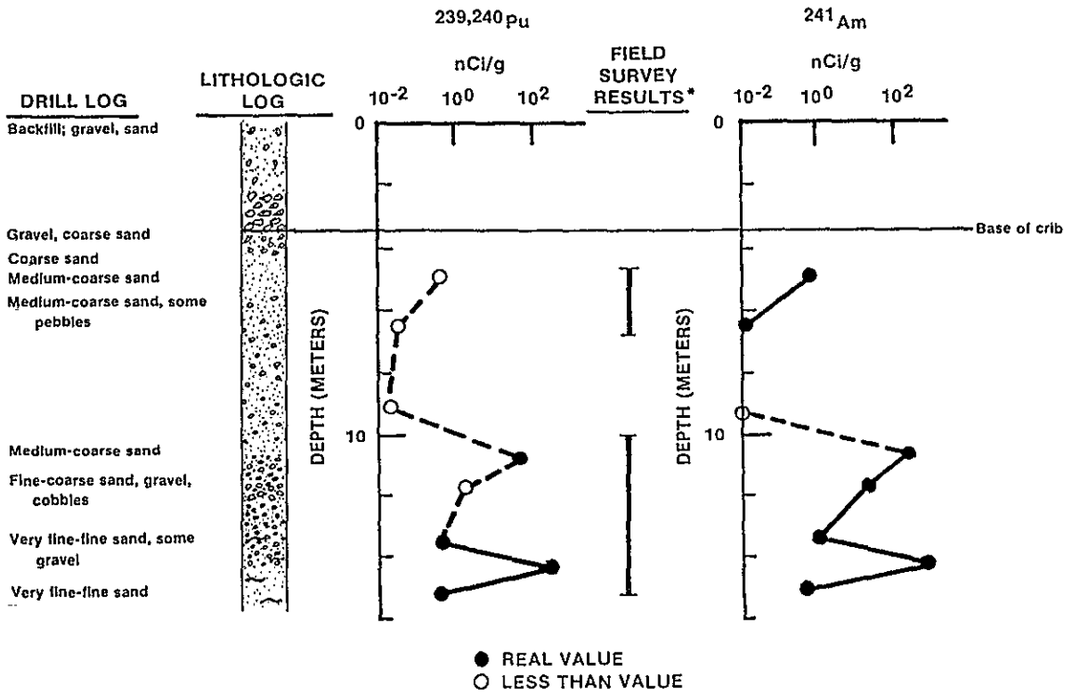
ELEVATION (METERS ABOVE MSL): 205.2



* ACTIVITY DETECTED WITH FIELD INSTRUMENTS

WELL 299-W18-174

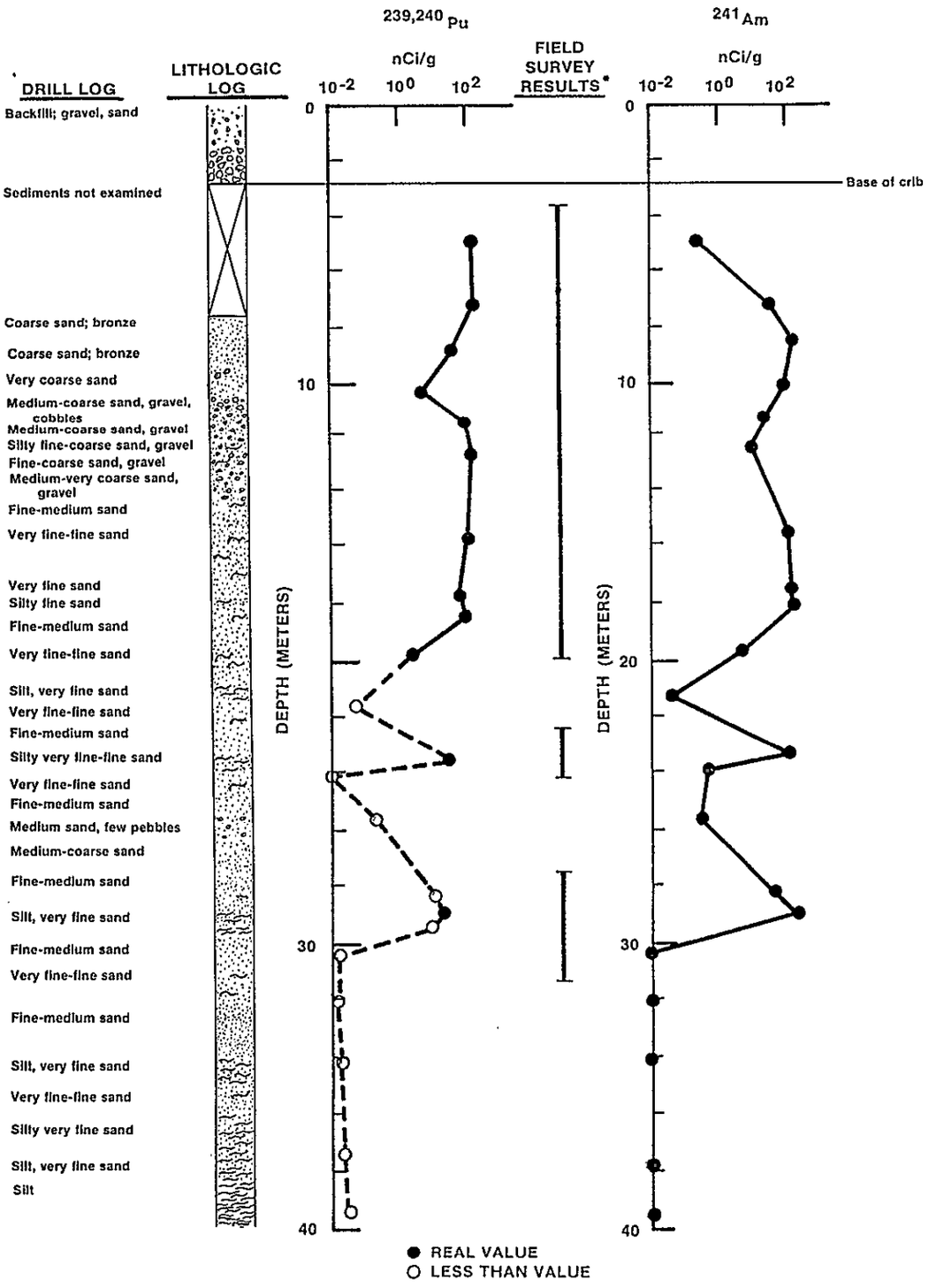
ELEVATION (METERS ABOVE MSL): 205.2



* ACTIVITY DETECTED WITH FIELD INSTRUMENTS

WELL 299-W18-175

ELEVATION (METERS ABOVE MSL): 204.7



* ACTIVITY DETECTED WITH FIELD INSTRUMENTS

APPENDIX C
GEOLOGIC CROSS SECTIONS

Appendix C consists of six cross sections (Plates 27 through 32) showing an interpretation of the geology beneath the 216-Z-1A Crib. The locations of the six cross sections, designated A-A' through F-F', are identified on a plan view of the crib (Plate 1).

The interpretation of the geology is based on the granulometric data and drill log descriptions contained in Appendix B. Geologic terminology follows the classification systems presented in Figures 12 and 13.

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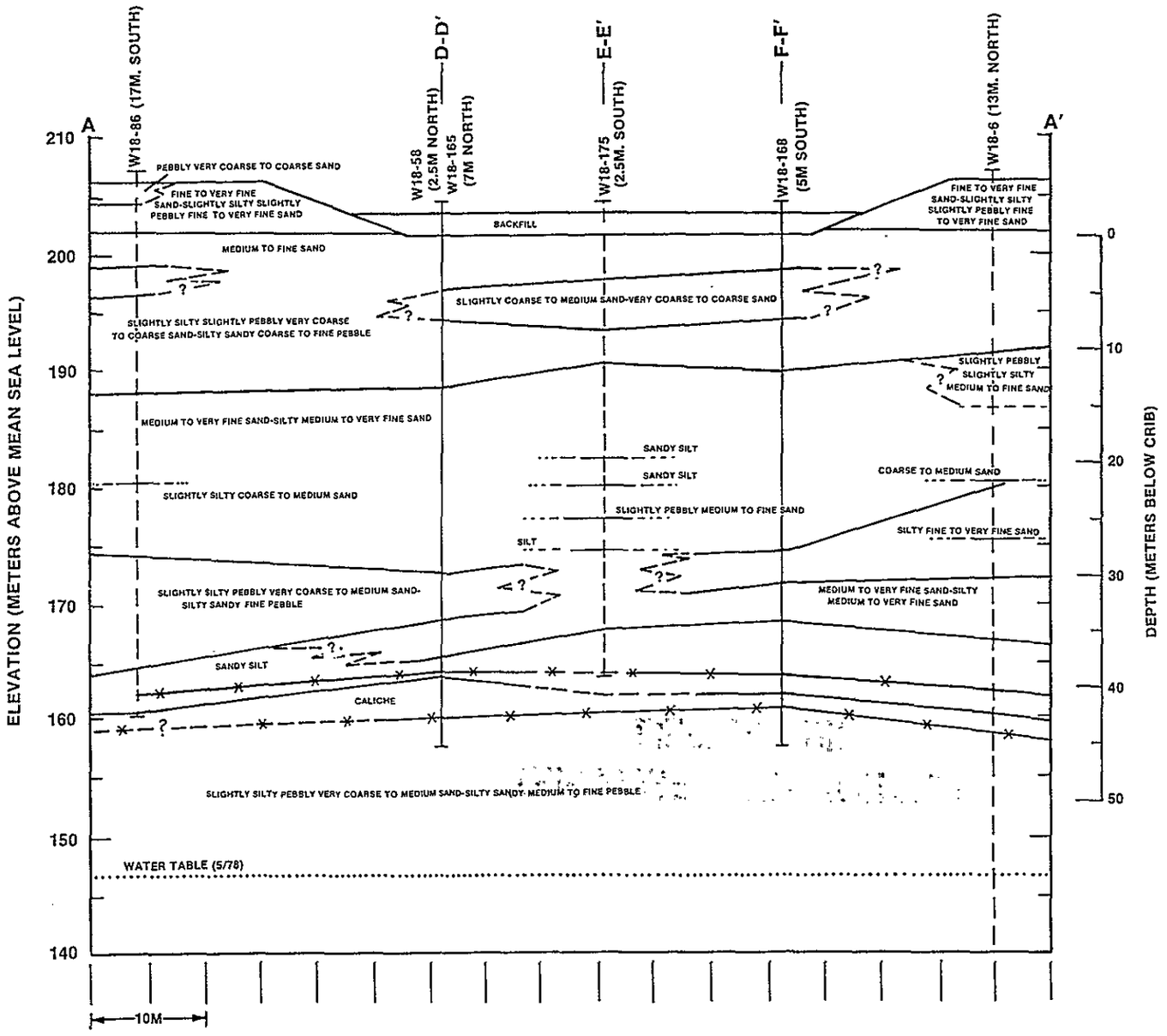

PLATE 27

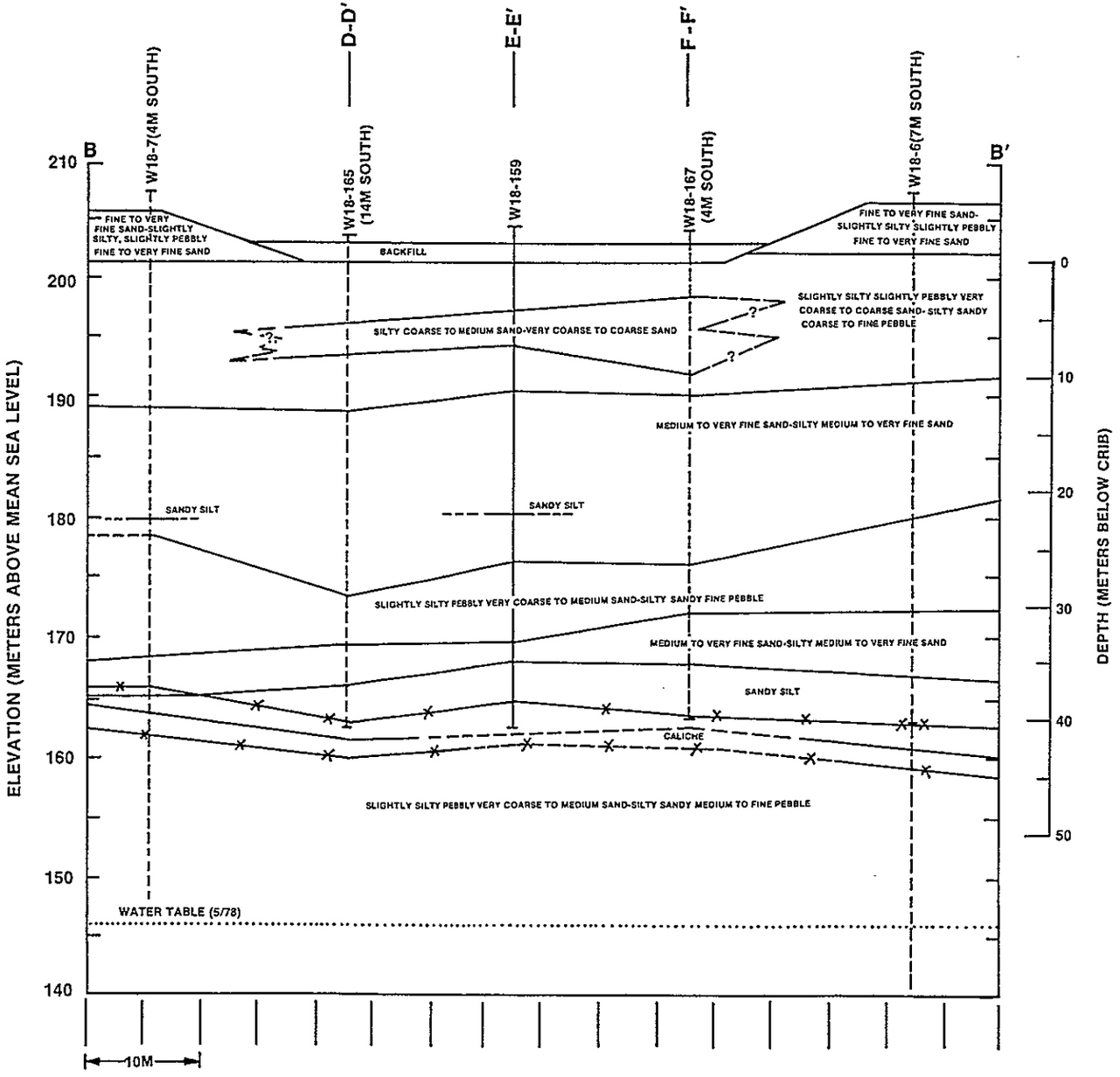

PLATE 28

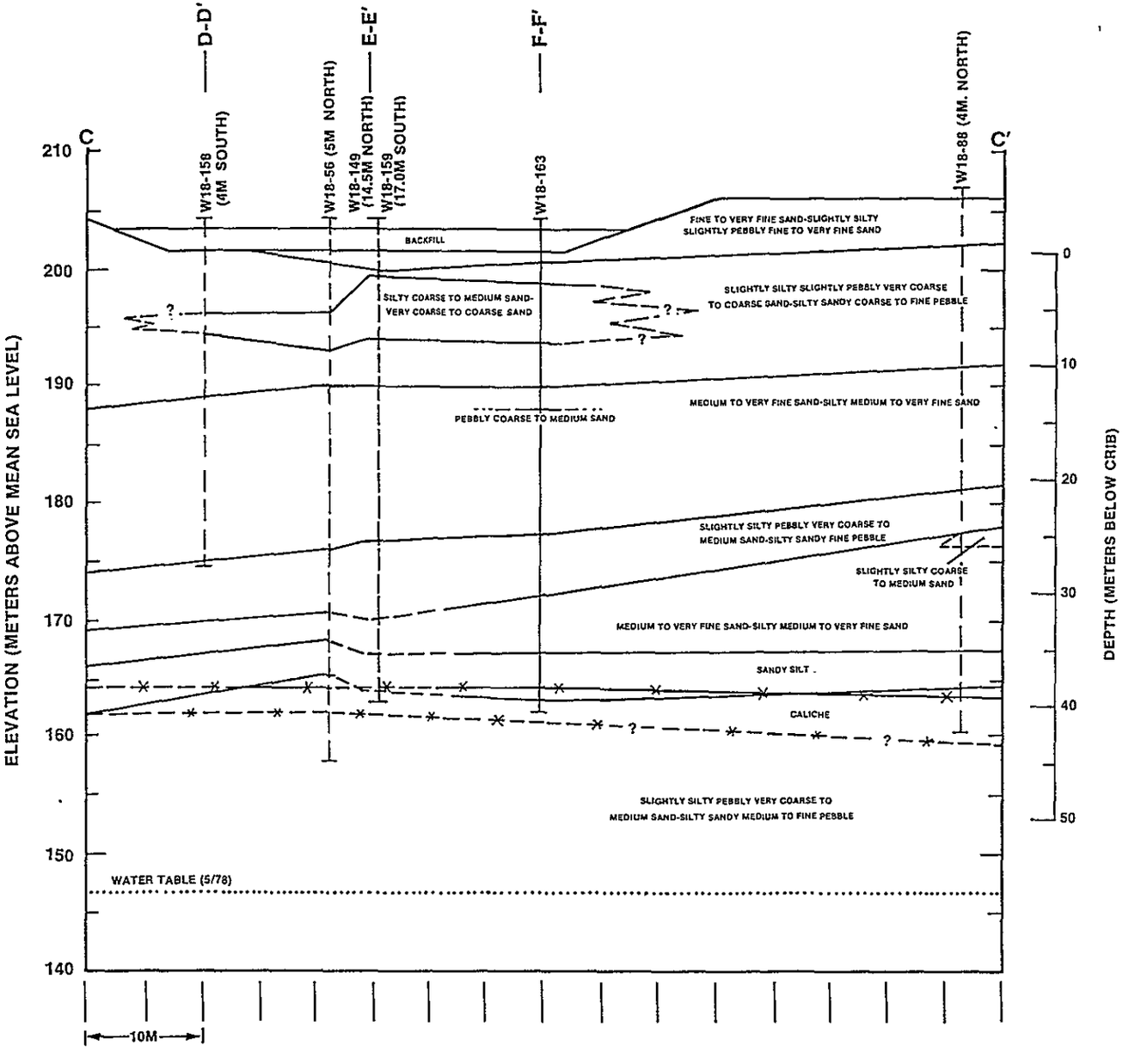

PLATE 29

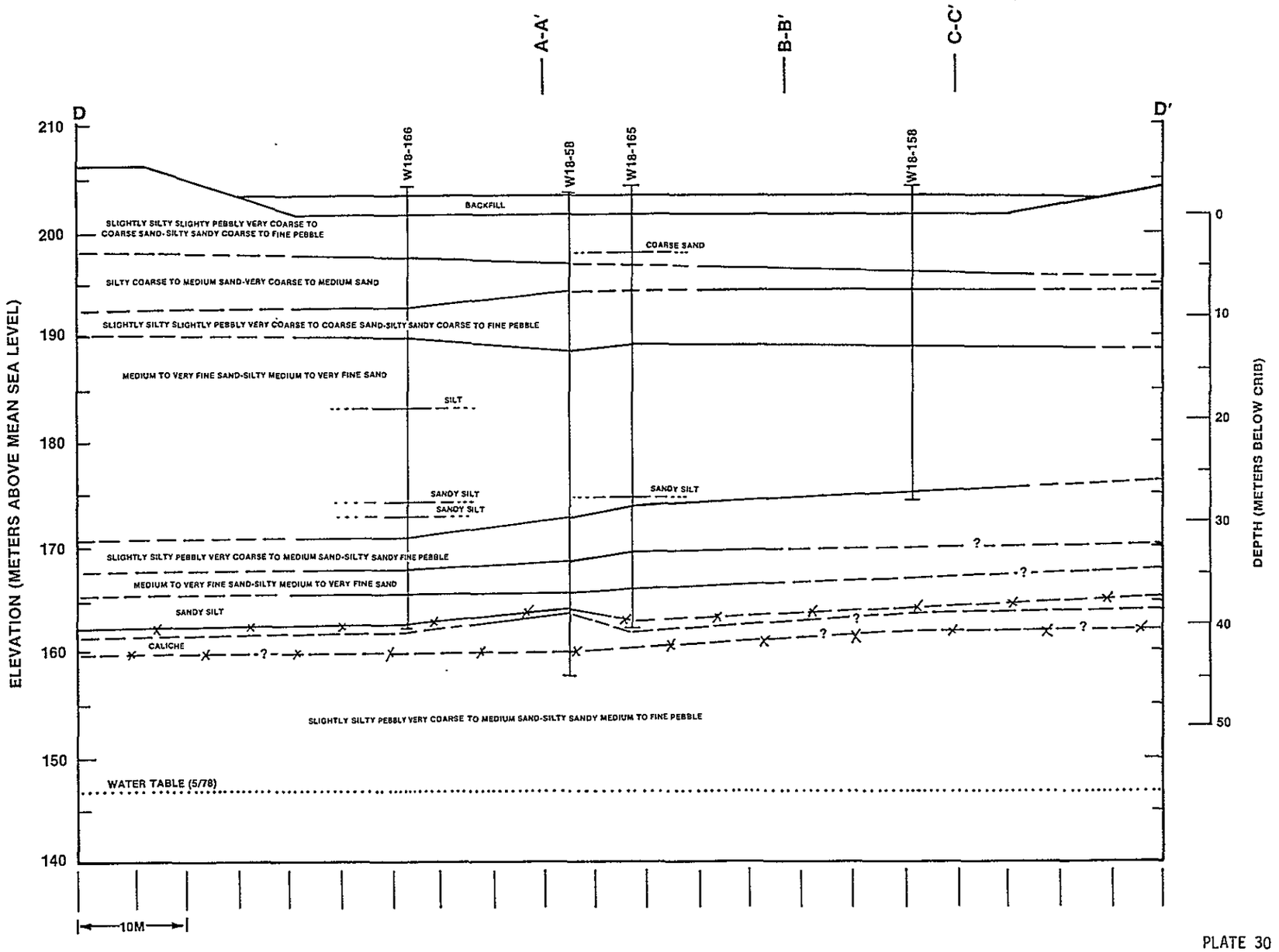

PLATE 30

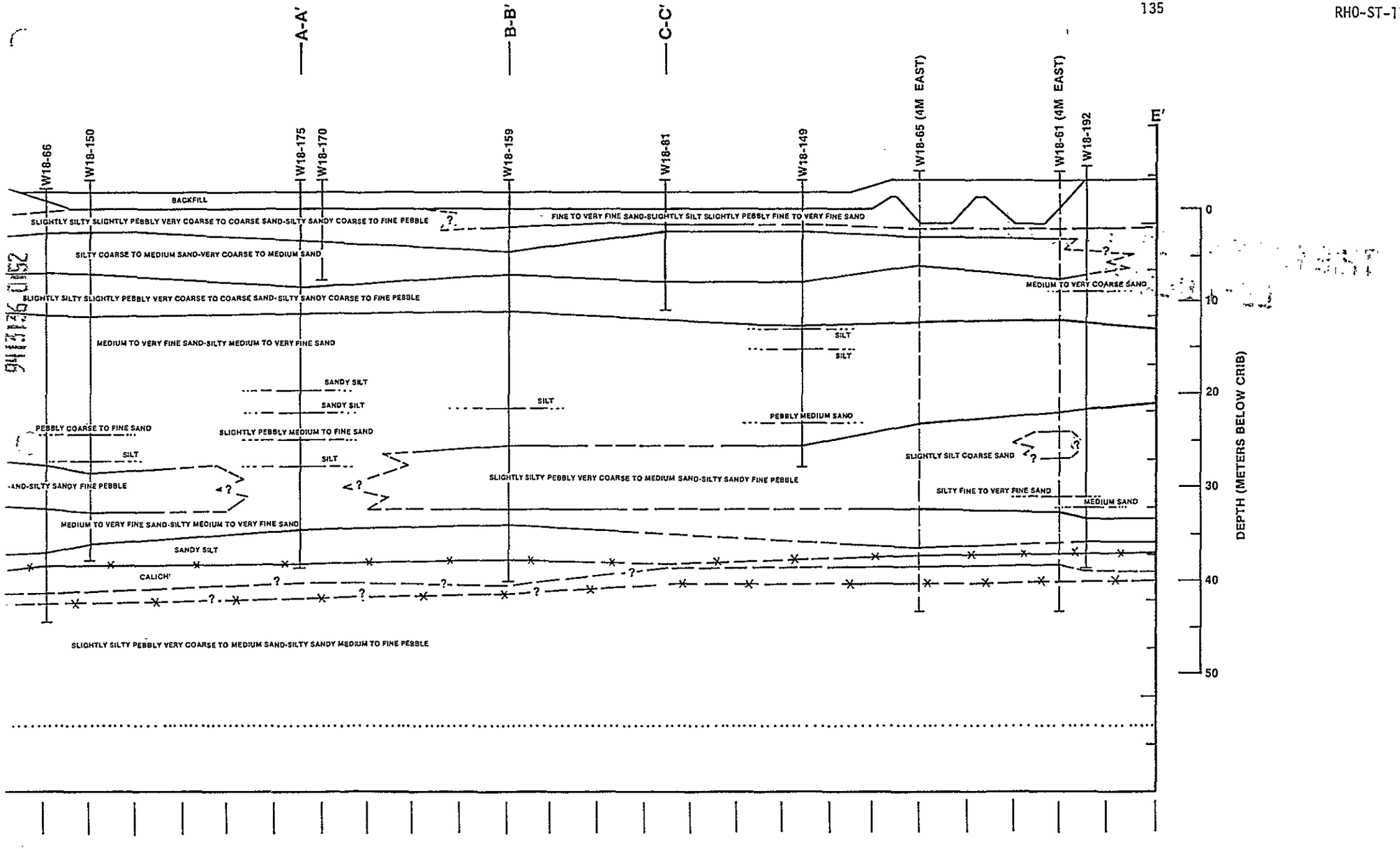
A-A'
B-B'
C-C'
E'
W18-66
W18-150
W18-175
W18-170
W18-159
W18-81
W18-149
W18-65 (4M EAST)
W18-61 (4M EAST)
W18-192
BACKFILL
SLIGHTLY SILTY SLIGHTLY PEBBLY VERY COARSE TO COARSE SAND-SILTY SANDY COARSE TO FINE PEBBLE
FINE TO VERY FINE SAND-SLIGHTLY SILT SLIGHTLY PEBBLY FINE TO VERY FINE SAND
SILTY COARSE TO MEDIUM SAND-VERY COARSE TO MEDIUM SAND
MEDIUM TO VERY COARSE SAND
SLIGHTLY SILTY SLIGHTLY PEBBLY VERY COARSE TO COARSE SAND-SILTY SANDY COARSE TO FINE PEBBLE
MEDIUM TO VERY FINE SAND-SILTY MEDIUM TO VERY FINE SAND
SILT
SILT
SANDY SILT
SANDY SILT
SILT
PEBBLY MEDIUM SAND
PEBBLY COARSE TO FINE SAND
SLIGHTLY PEBBLY MEDIUM TO FINE SAND
SILT
SILT
SLIGHTLY SILT COARSE SAND
AND-SILTY SANDY FINE PEBBLE
SLIGHTLY SILTY PEBBLY VERY COARSE TO MEDIUM SAND-SILTY SANDY FINE PEBBLE
SILTY FINE TO VERY FINE SAND
MEDIUM SAND
MEDIUM TO VERY FINE SAND-SILTY MEDIUM TO VERY FINE SAND
SANDY SILT
CALICH'
SLIGHTLY SILTY PEBBLY VERY COARSE TO MEDIUM SAND-SILTY SANDY MEDIUM TO FINE PEBBLE
0
10
20
30
40
50
DEPTH (METERS BELOW CRIB)

PLATE 31

RHO-ST-17

Page 135A

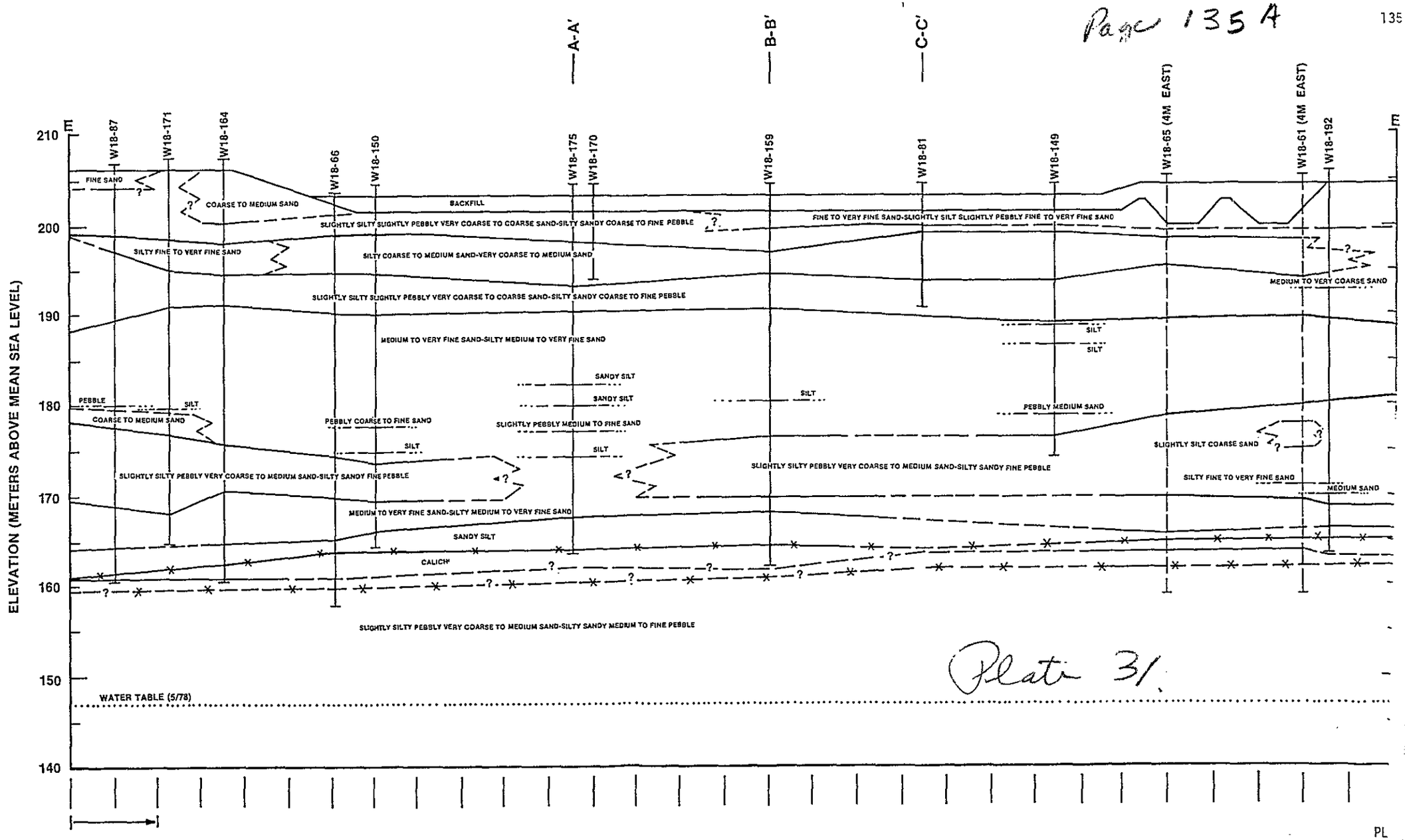

Plate 31.

PL

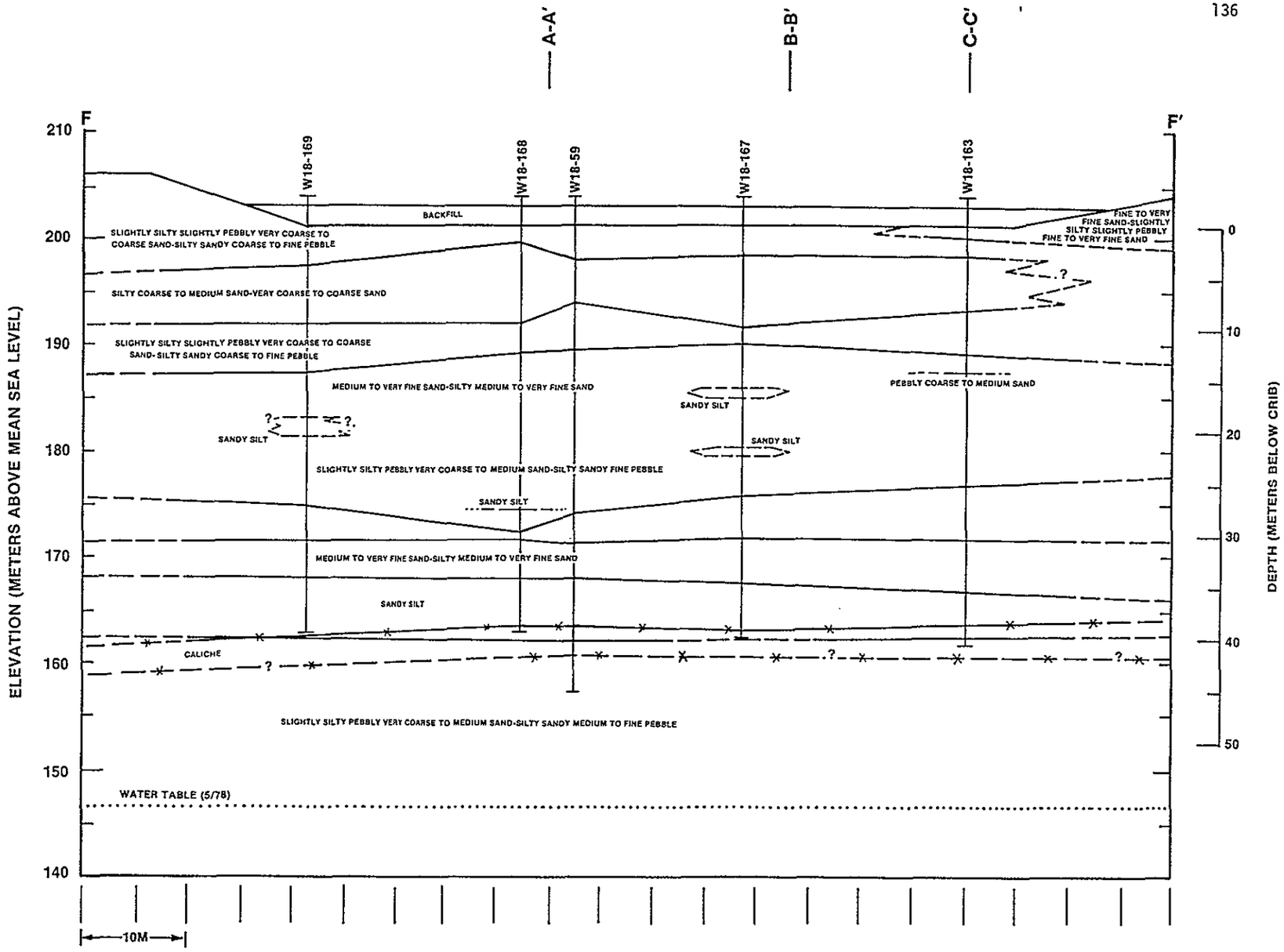

PLATE 32

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APPENDIX D

ISOPLETH CROSS SECTIONS FOR PLUTONIUM, AMERICIUM, AND TOTAL ACTIVITY

Appendix D contains 18 isopleth cross sections (Plates 33 through 50) showing an interpretation of actinide distribution beneath the 216-Z-1A Crib. The six geologic cross sections contained in Appendix C (A-A' through F-F', Plate 1) are used as the base for these isopleth cross sections. To simplify the plates within Appendix D, the geological terminology has been generalized and only the wells used to determine actinide distribution located.

For each geologic cross section, individual isopleth cross sections are presented showing the distribution of plutonium, americium, and total activity (plutonium plus americium, see Glossary). Five levels of activity are used to characterize the actinide distribution: 1) greater than 10^{2} nCi/g; 2) 10^{1} to 10^{2} nCi/g; 3) 10^{-1} to 10^{1} nCi/g; 4) 10^{-2} to 10^{-1} nCi/g; and 5) less than 10^{-2} nCi/g. The interpretation of the actinide distribution is based on: 1) analytical data reported in Appendix A; 2) portable radiation survey instrument measurements reported in Appendix B; and 3) scintillation probe data.[8]

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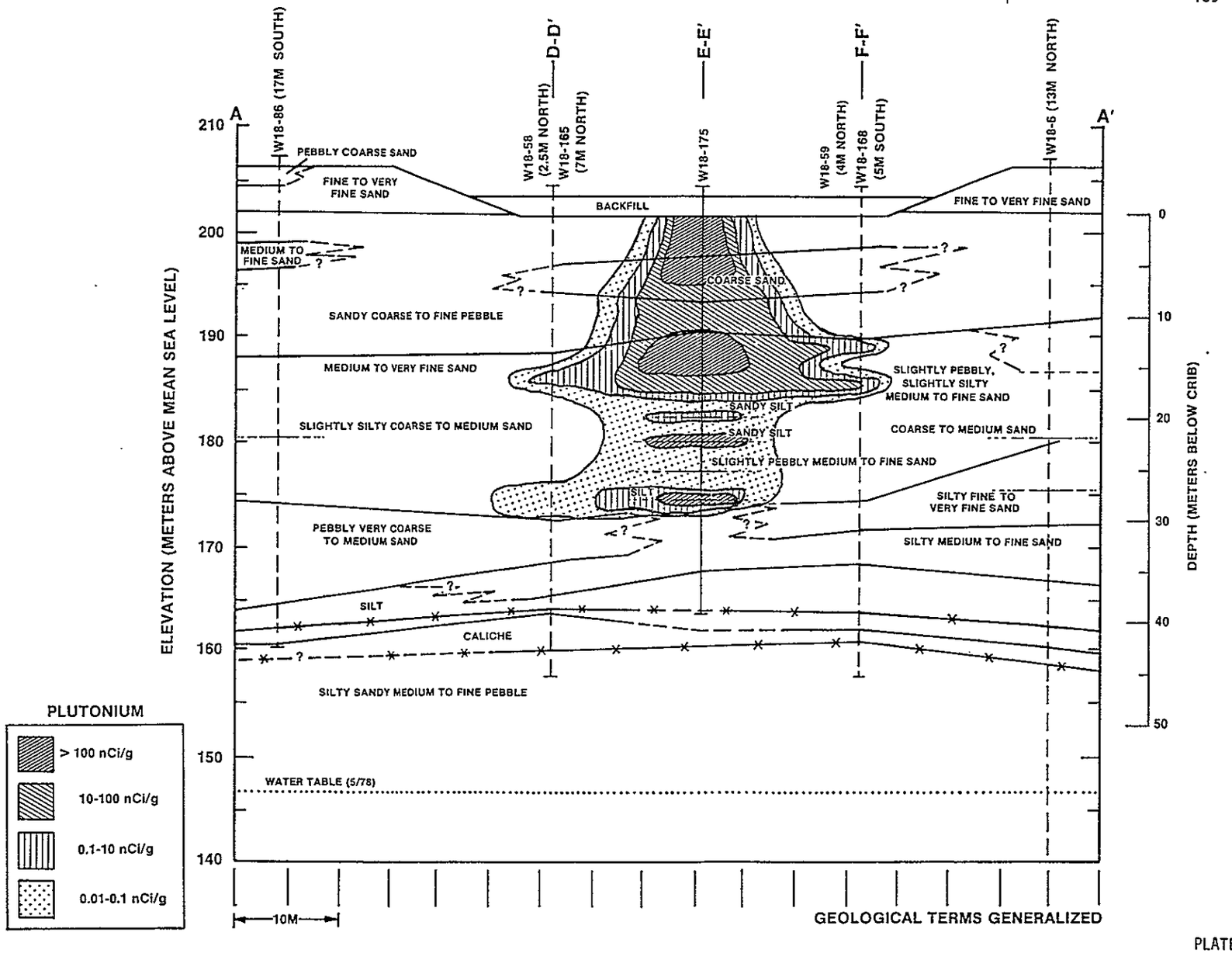


PLATE 33

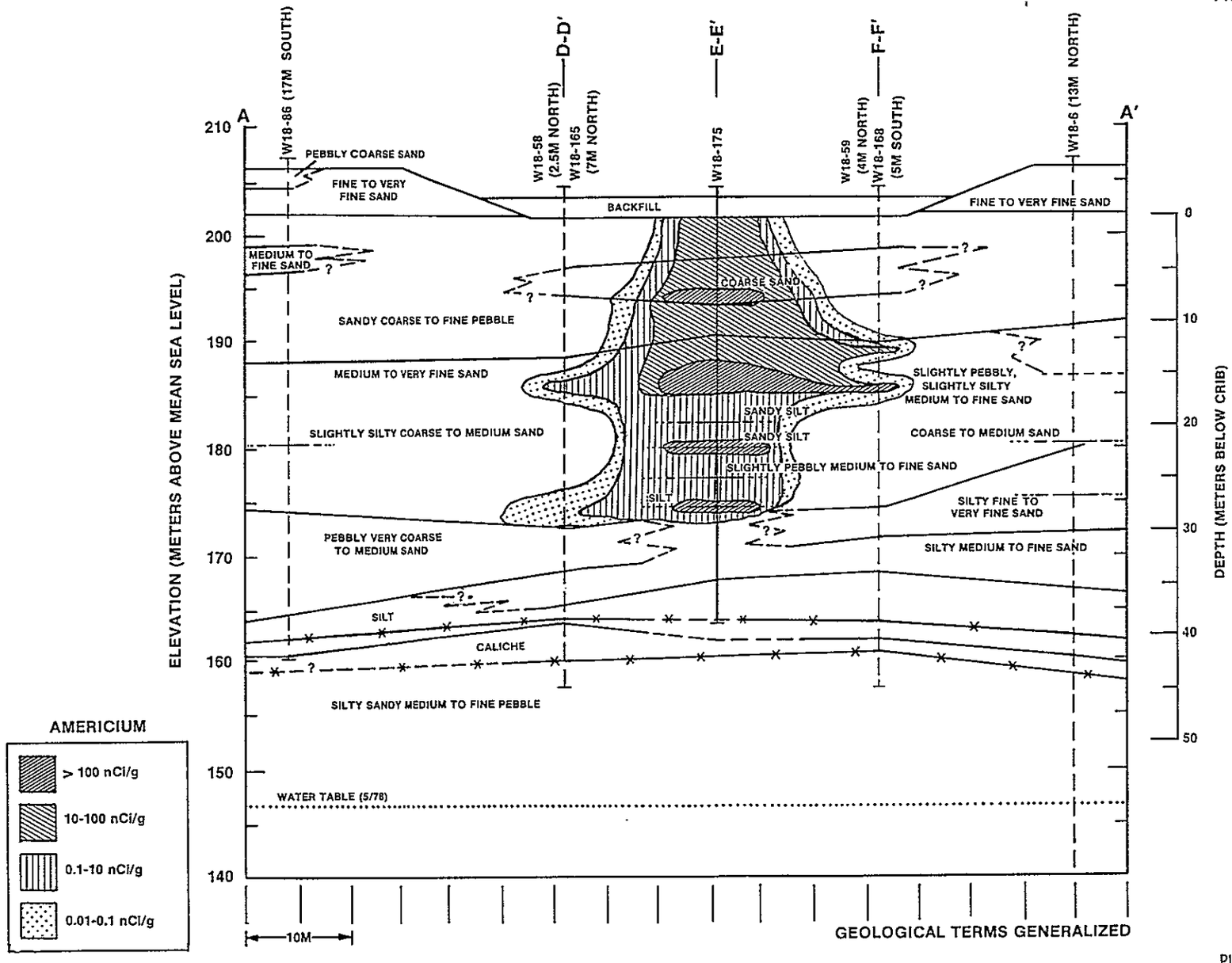
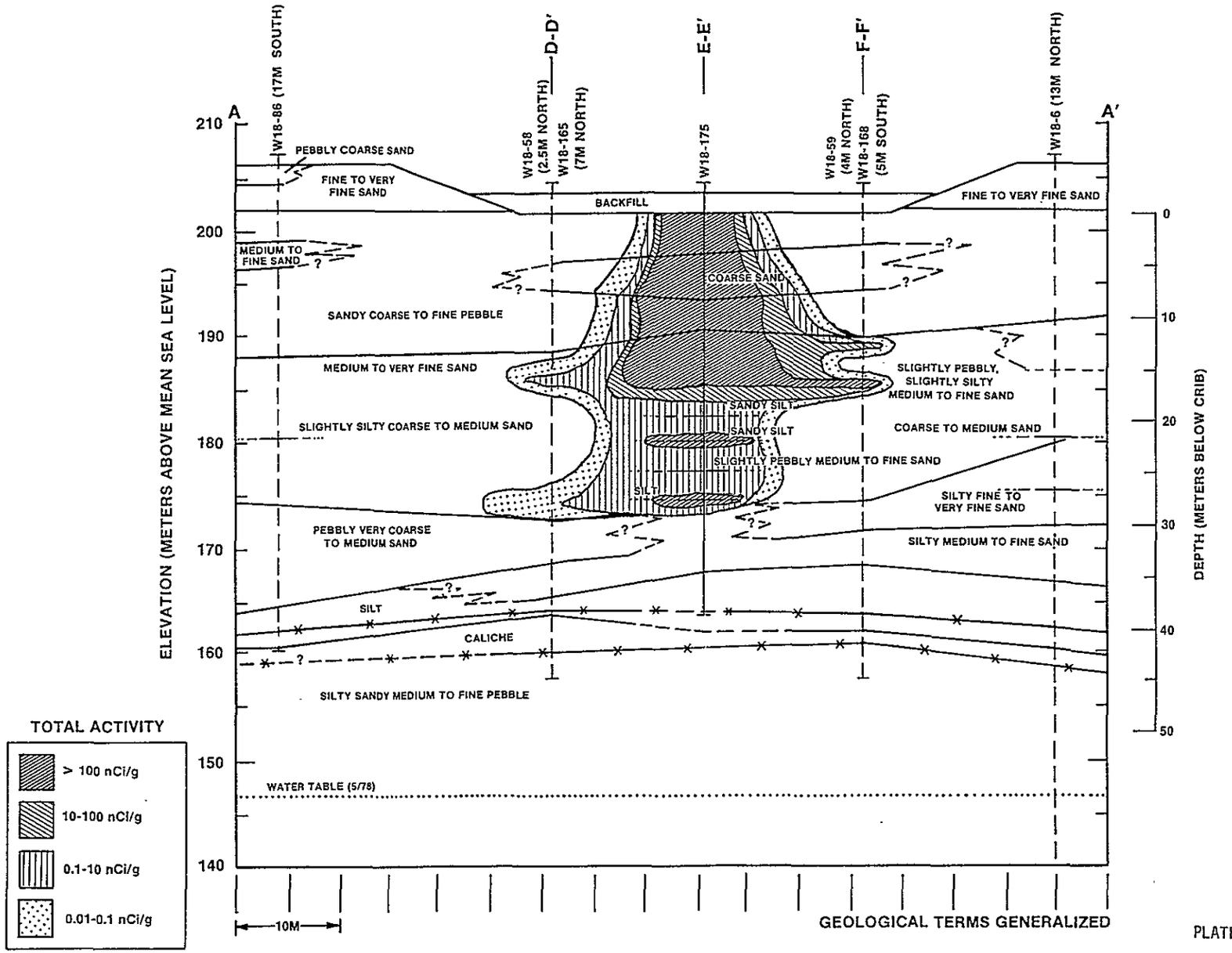


PLATE 34



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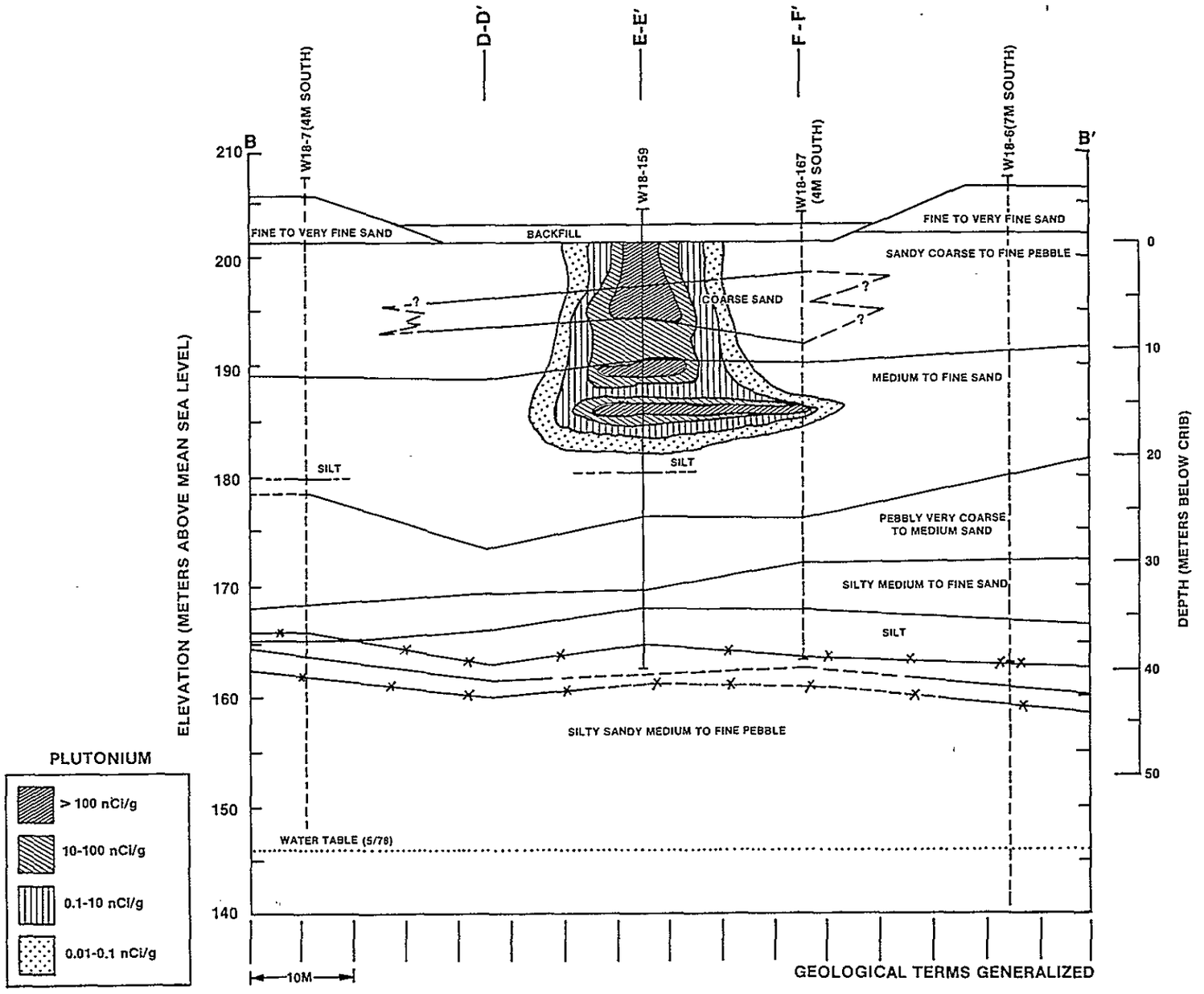

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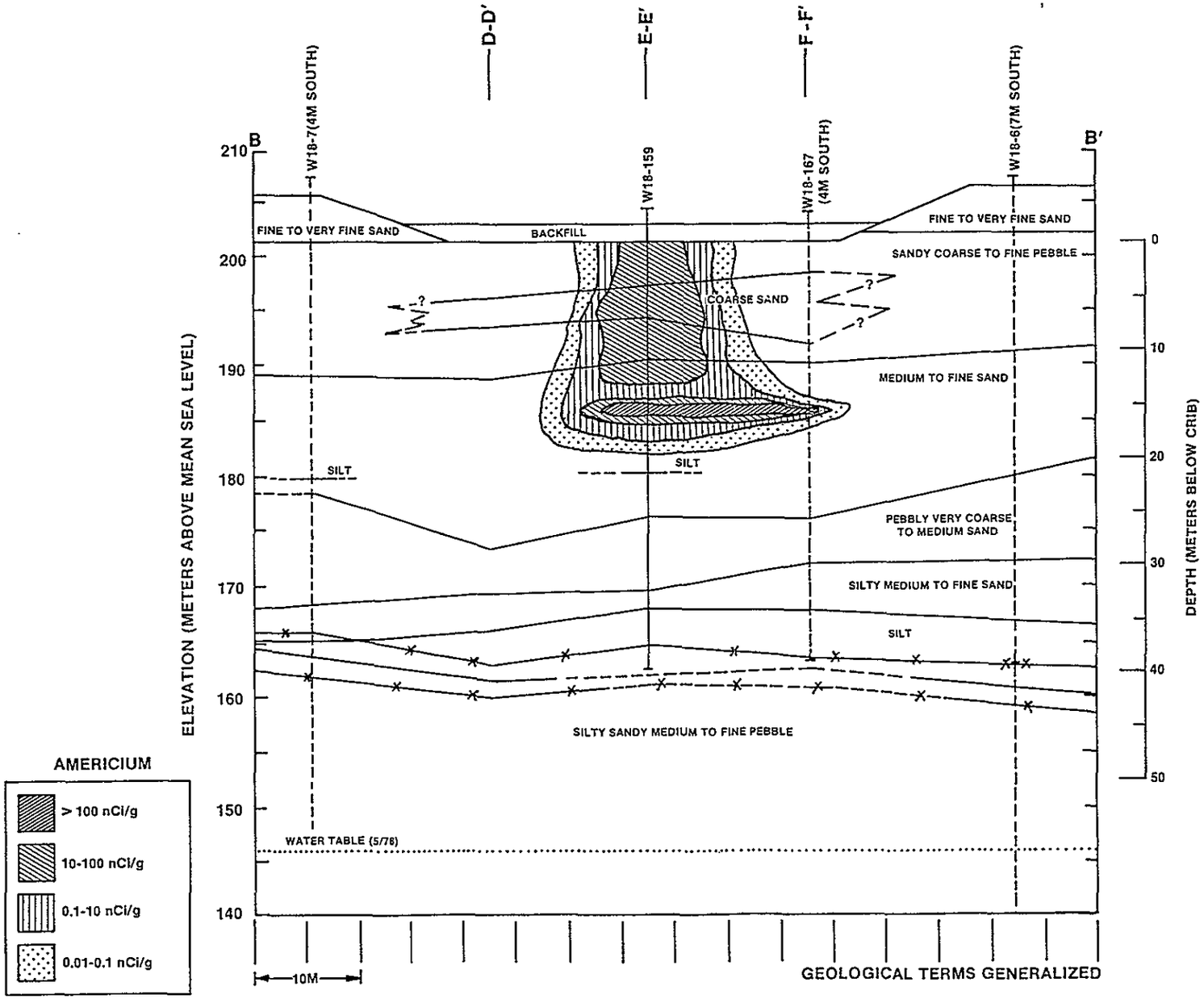

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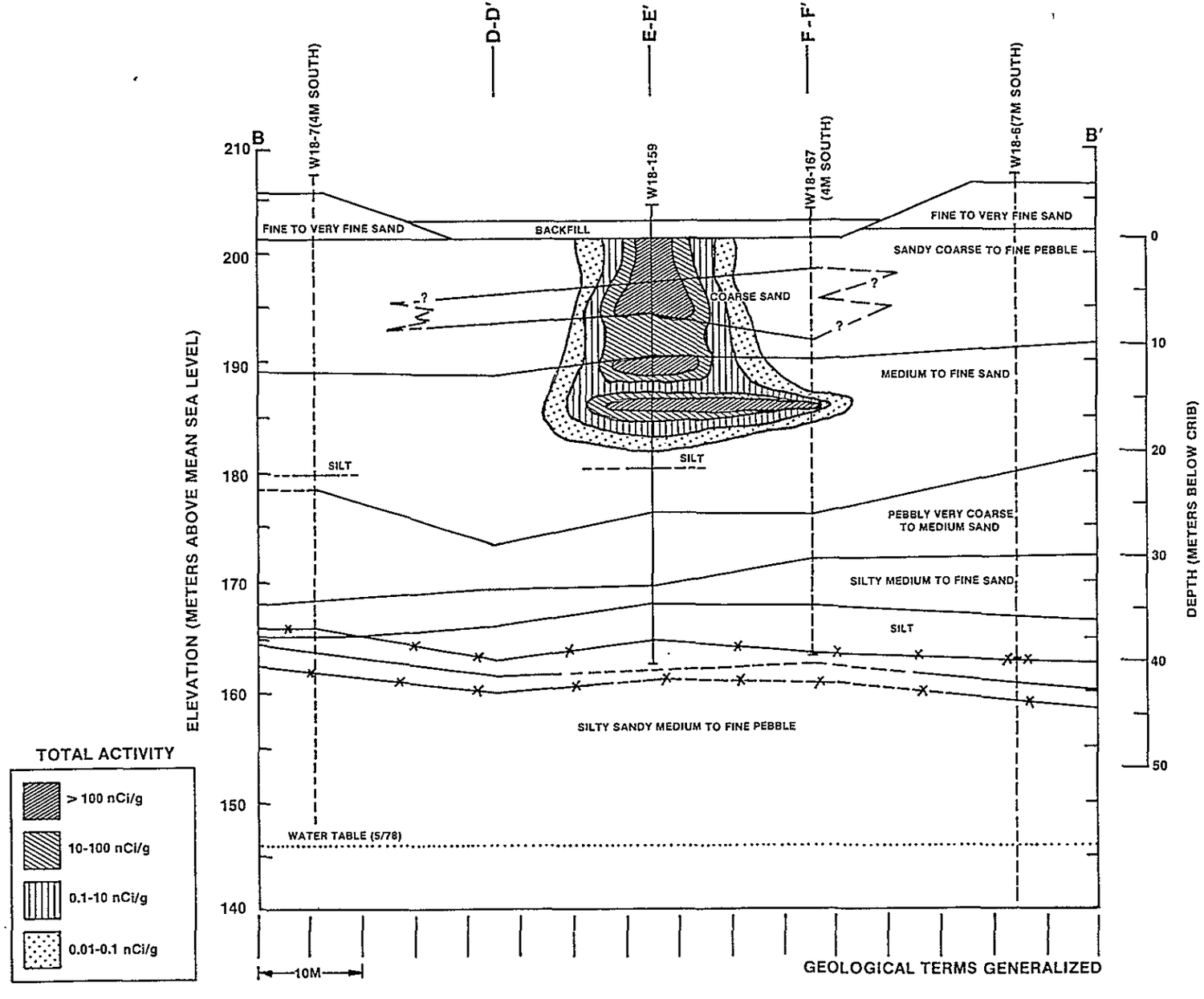

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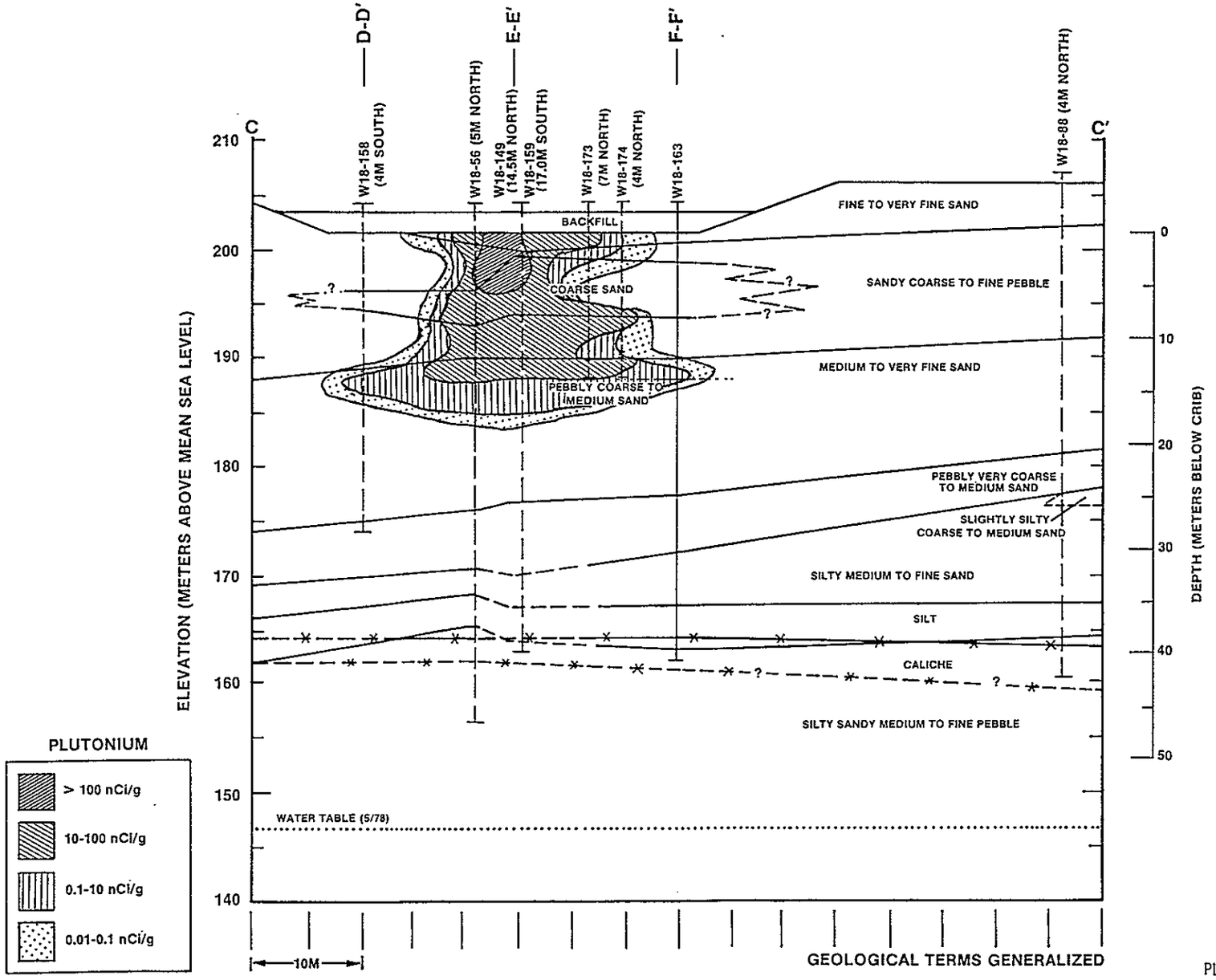

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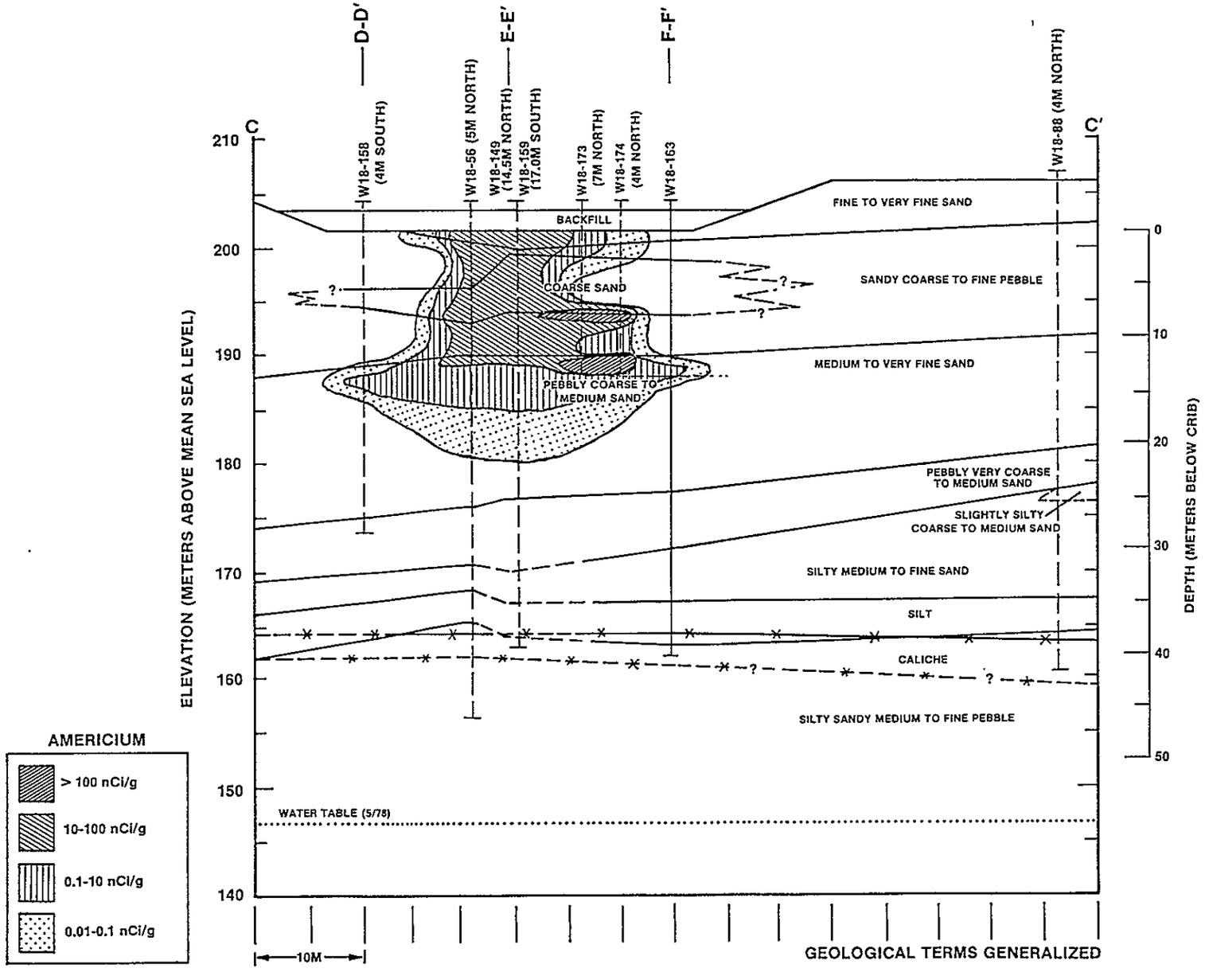

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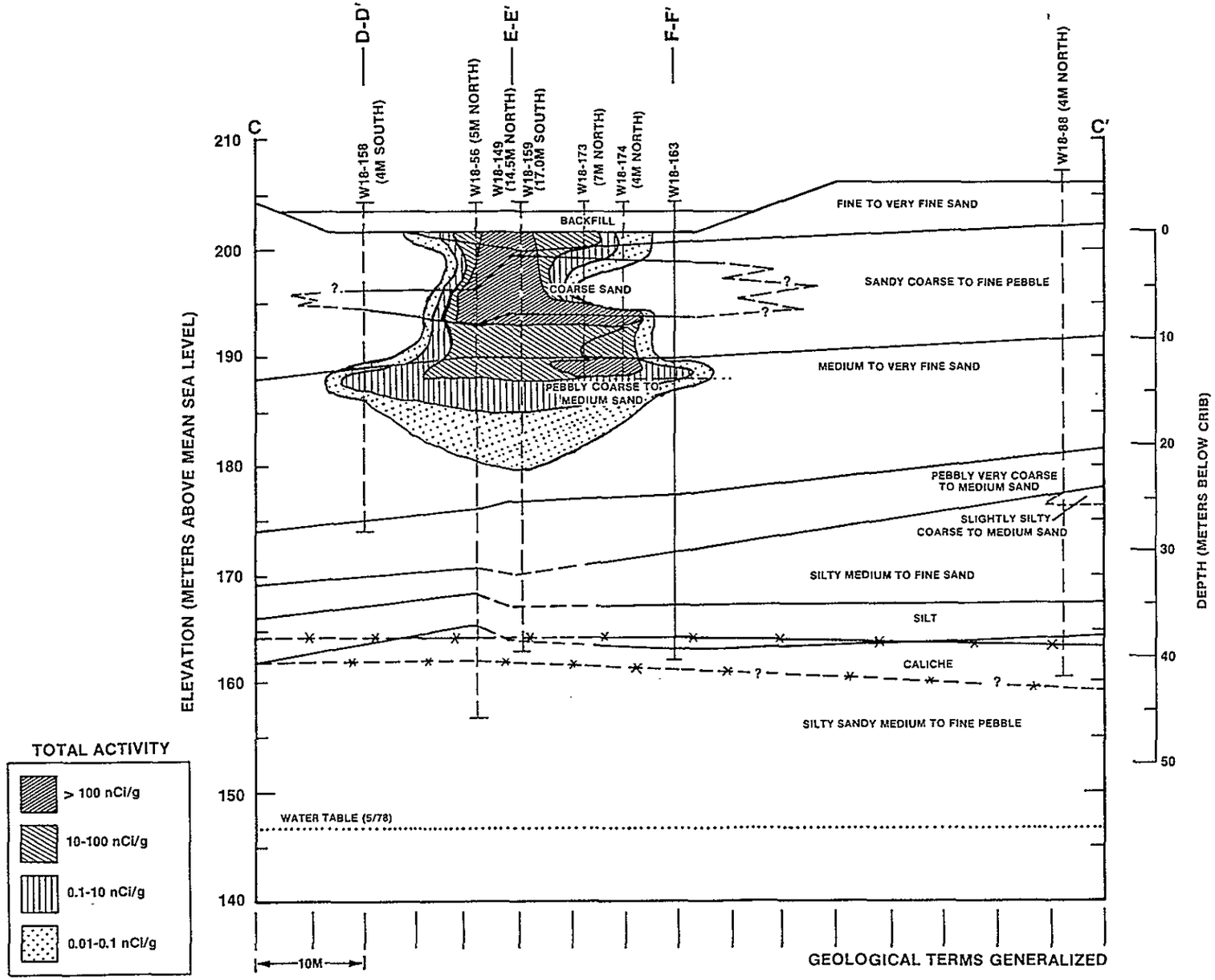

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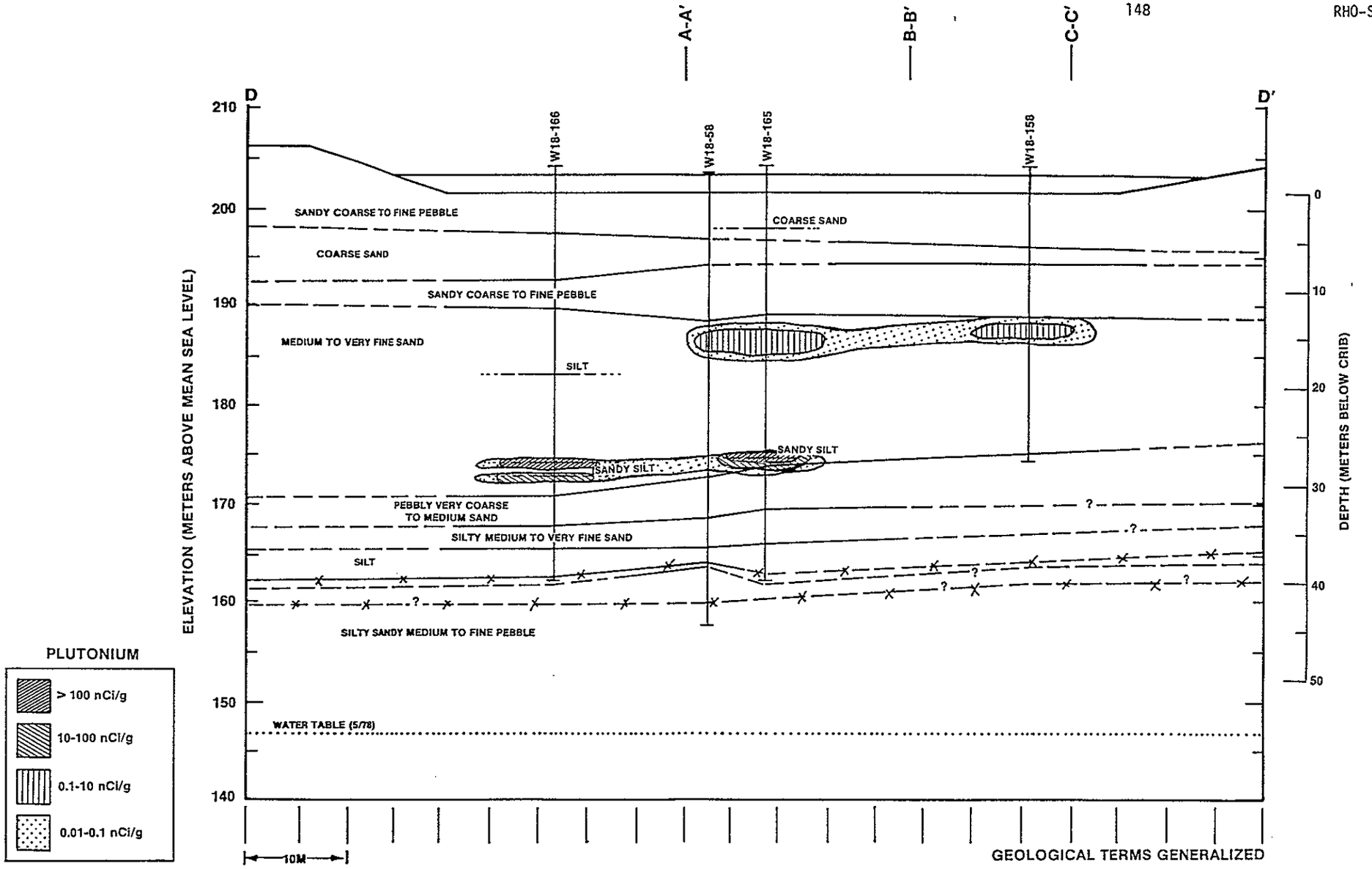

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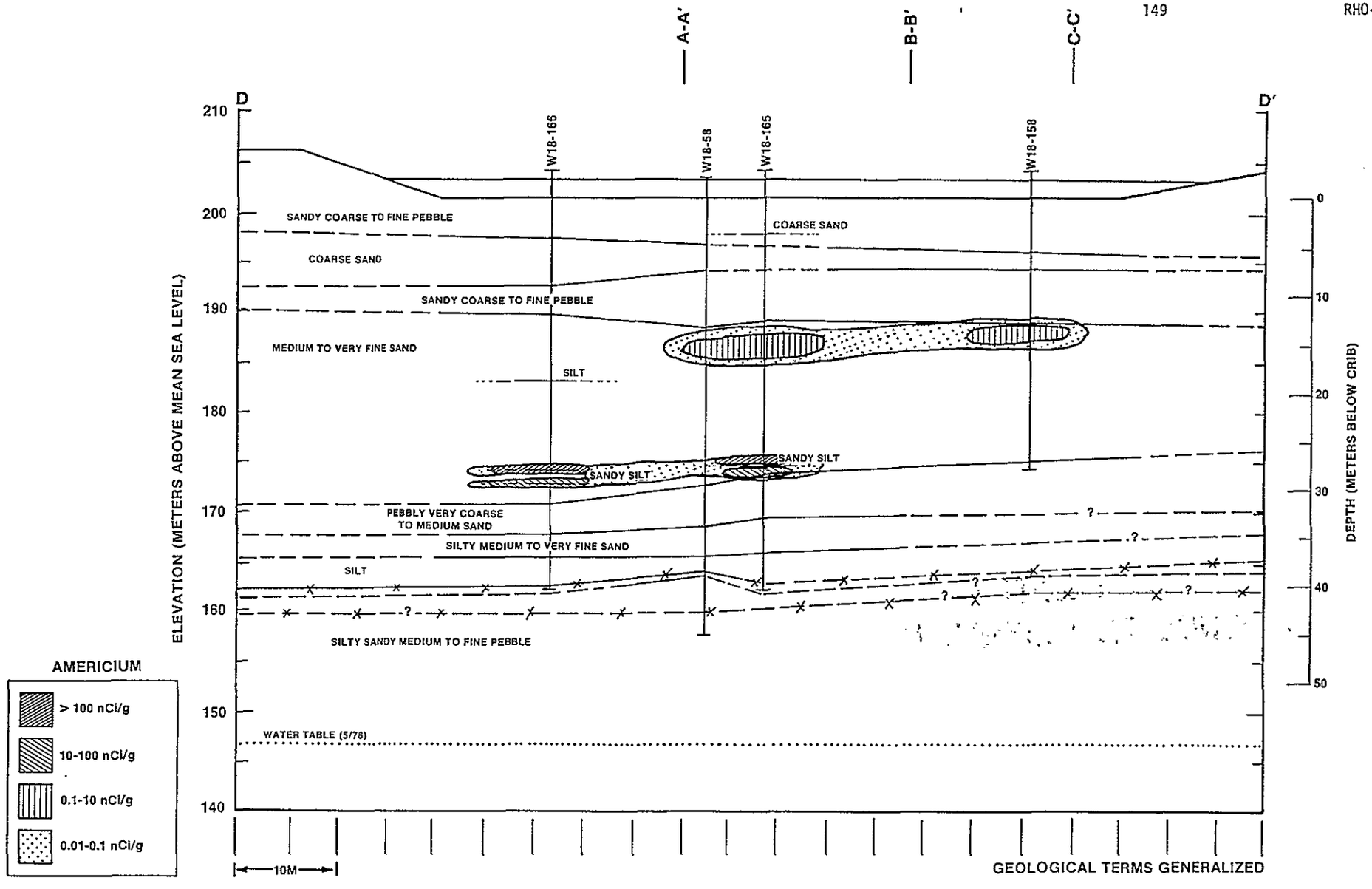

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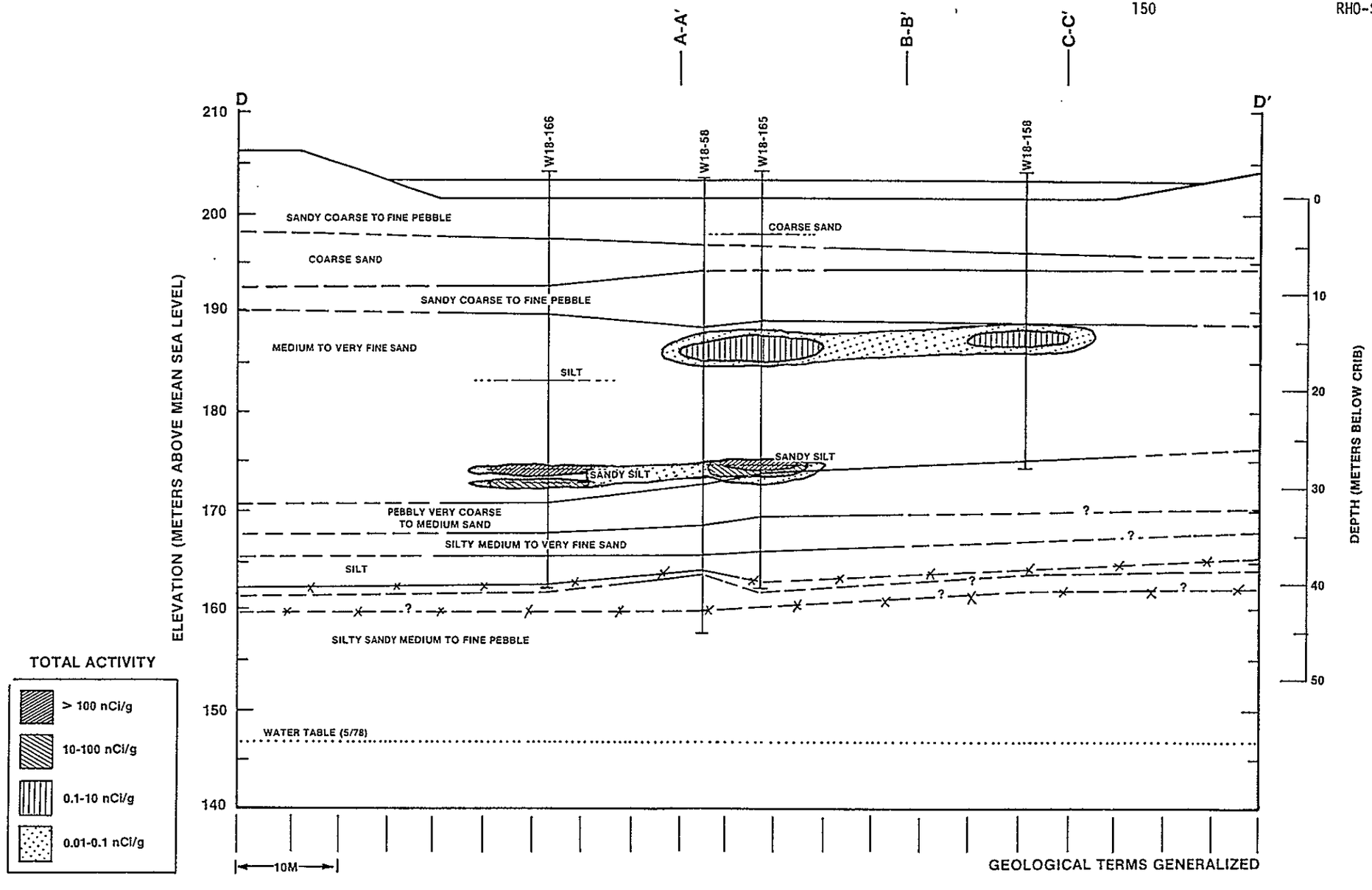

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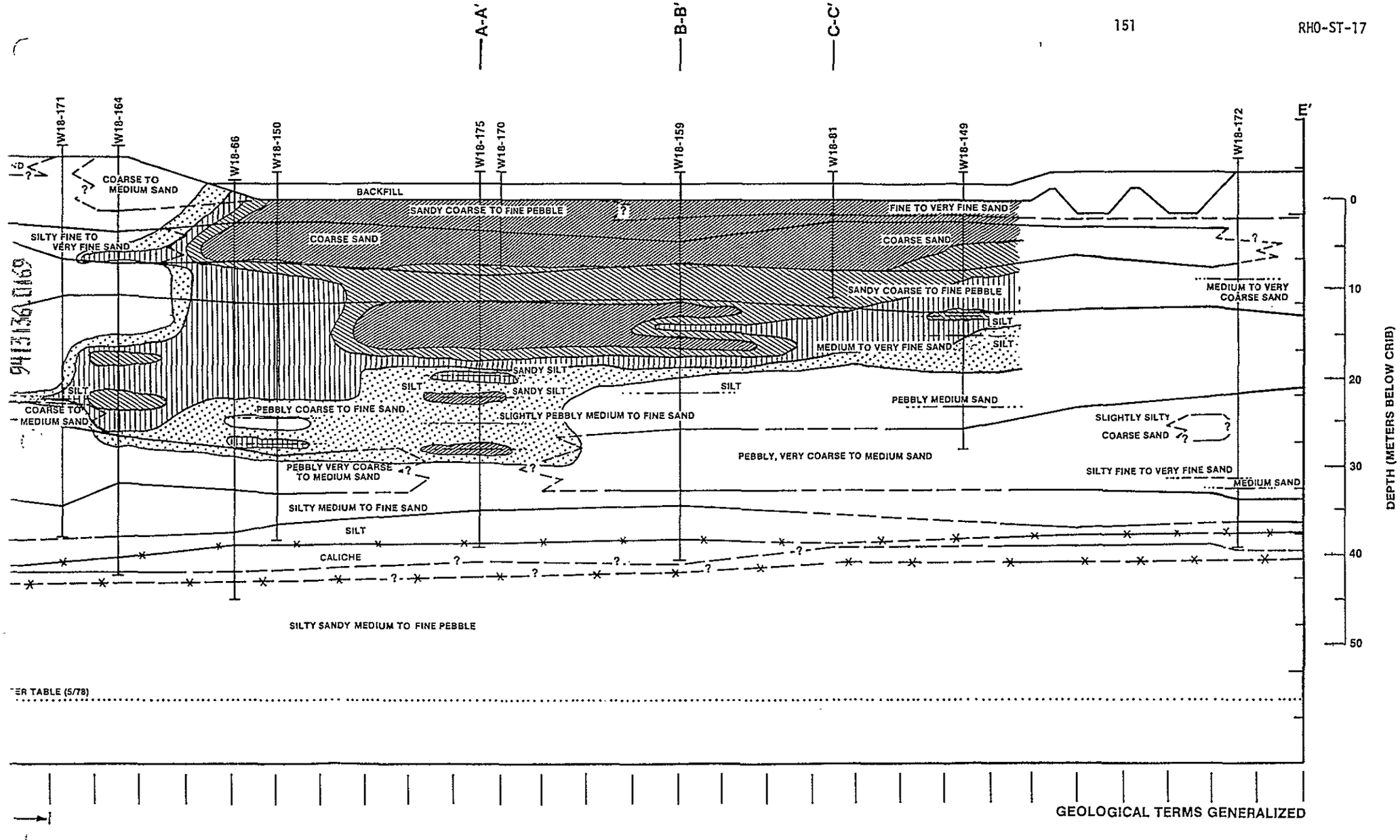

A-A'
B-B'
C-C'
W18-171
W18-164
W18-66
W18-150
W18-175
W18-170
W18-159
W18-81
W18-149
W18-172
E'
COARSE TO MEDIUM SAND
BACKFILL
SANDY COARSE TO FINE PEBBLE
FINE TO VERY FINE SAND
SILTY FINE TO VERY FINE SAND
COARSE SAND
SANDY COARSE TO FINE PEBBLE
MEDIUM TO VERY COARSE SAND
SILT
MEDIUM TO VERY FINE SAND
SANDY SILT
PEBBLY MEDIUM SAND
PEBBLY COARSE TO FINE SAND
SLIGHTLY PEBBLY MEDIUM TO FINE SAND
SLIGHTLY SILTY COARSE SAND
PEBBLY, VERY COARSE TO MEDIUM SAND
PEBBLY VERY COARSE TO MEDIUM SAND
SILTY FINE TO VERY FINE SAND
MEDIUM SAND
SILTY MEDIUM TO FINE SAND
CALICHE
SILTY SANDY MEDIUM TO FINE PEBBLE
ER TABLE (5/78)
0
10
20
30
40
50
DEPTH (METERS BELOW CRIB)
GEOLOGICAL TERMS GENERALIZED

PLATE 45

RHO-ST-17

Page 151A

9413136.0170

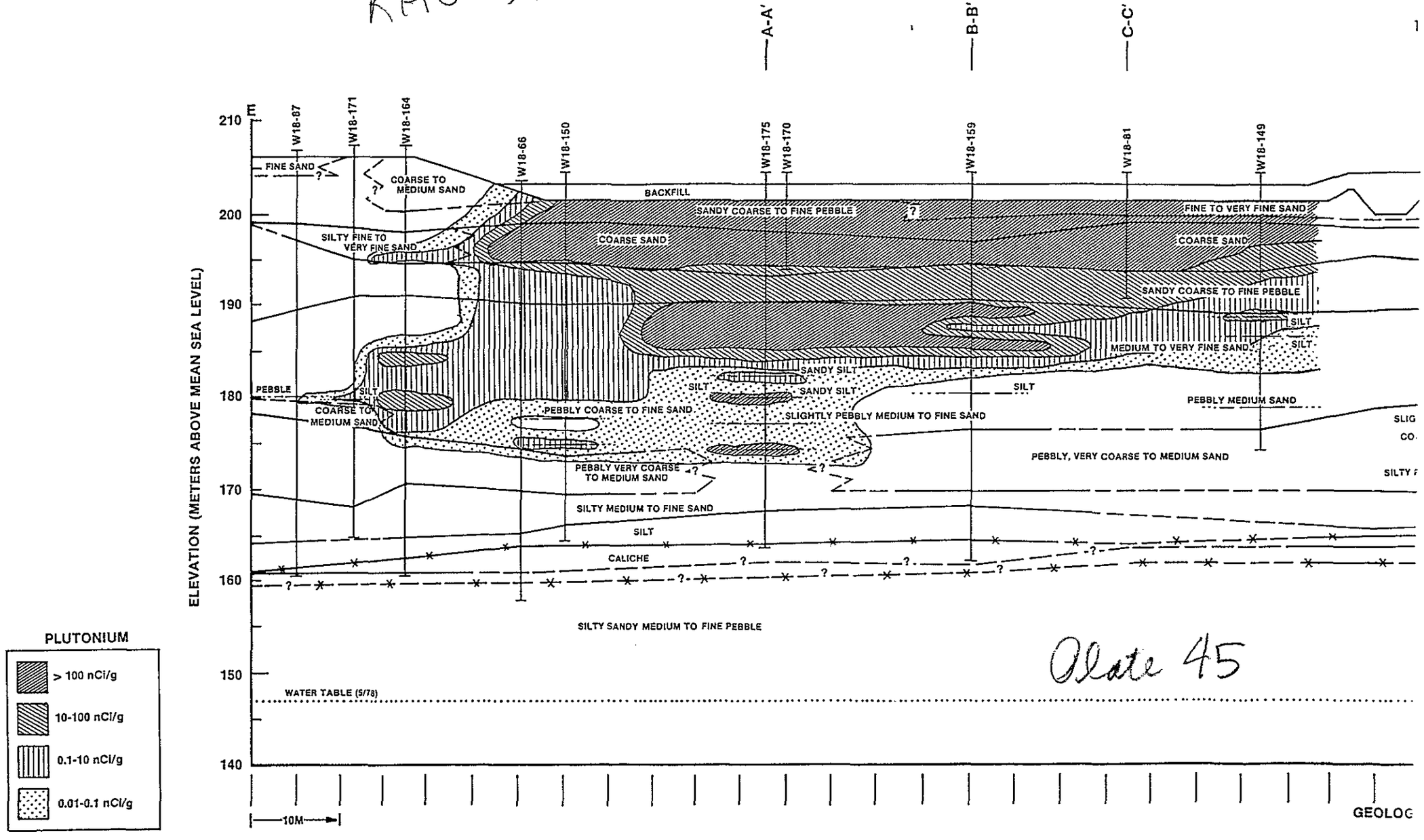
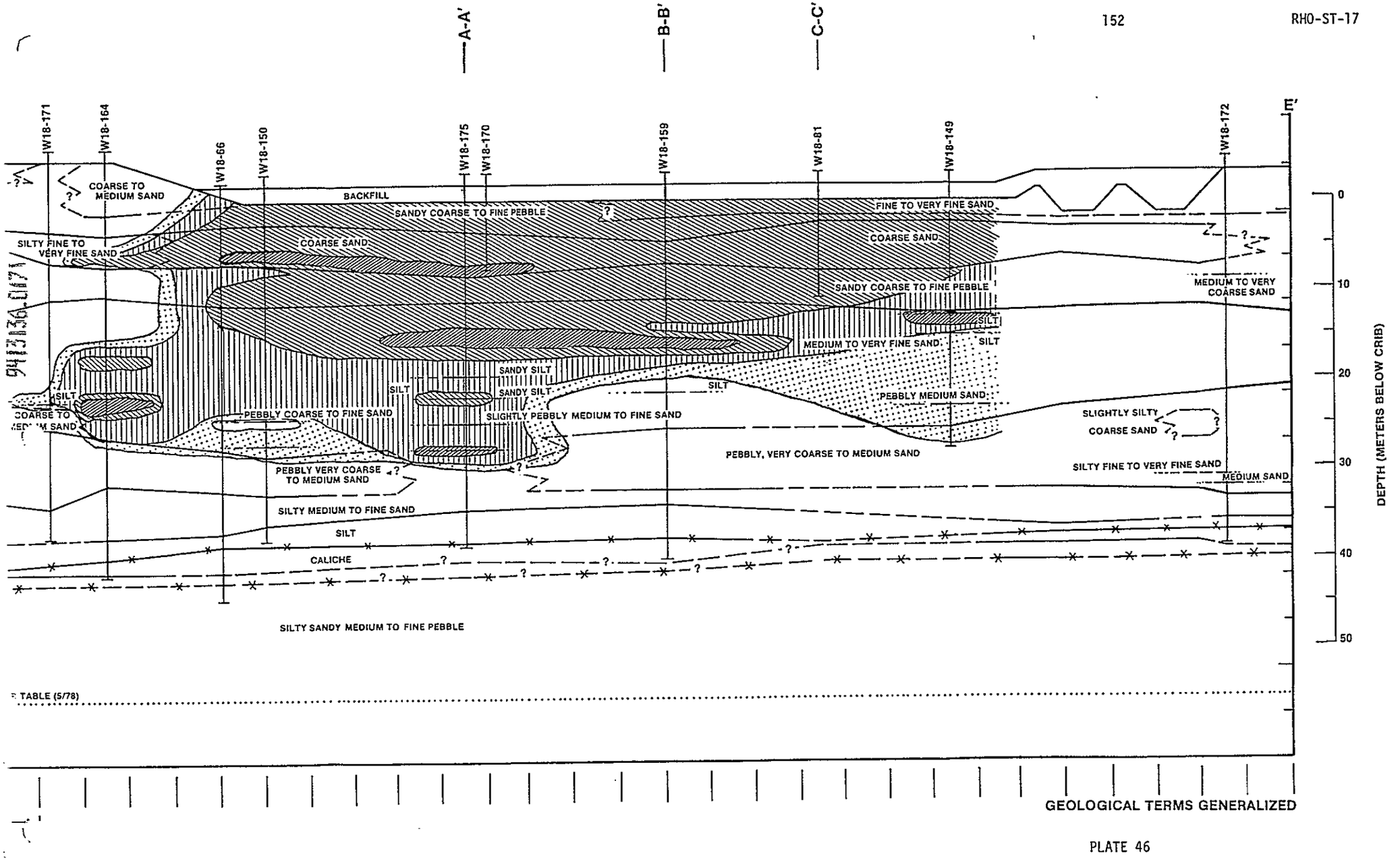


Plate 45


A-A'
B-B'
C-C'
W18-171
W18-164
W18-66
W18-150
W18-175
W18-170
W18-159
W18-81
W18-149
W18-172
COARSE TO MEDIUM SAND
BACKFILL
SANDY COARSE TO FINE PEBBLE
FINE TO VERY FINE SAND
SILTY FINE TO VERY FINE SAND
COARSE SAND
MEDIUM TO VERY COARSE SAND
SILT
MEDIUM TO VERY FINE SAND
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PEBBLY MEDIUM SAND
PEBBLY COARSE TO FINE SAND
SLIGHTLY PEBBLY MEDIUM TO FINE SAND
SLIGHTLY SILTY COARSE SAND
PEBBLY, VERY COARSE TO MEDIUM SAND
PEBBLY VERY COARSE TO MEDIUM SAND
SILTY FINE TO VERY FINE SAND
MEDIUM SAND
SILTY MEDIUM TO FINE SAND
CALICHE
SILTY SANDY MEDIUM TO FINE PEBBLE
TABLE (5/78)
DEPTH (METERS BELOW CRIB)
0
10
20
30
40
50
GEOLOGICAL TERMS GENERALIZED

PLATE 46

RHO-ST-17

Page 15 of A

9113136-0172

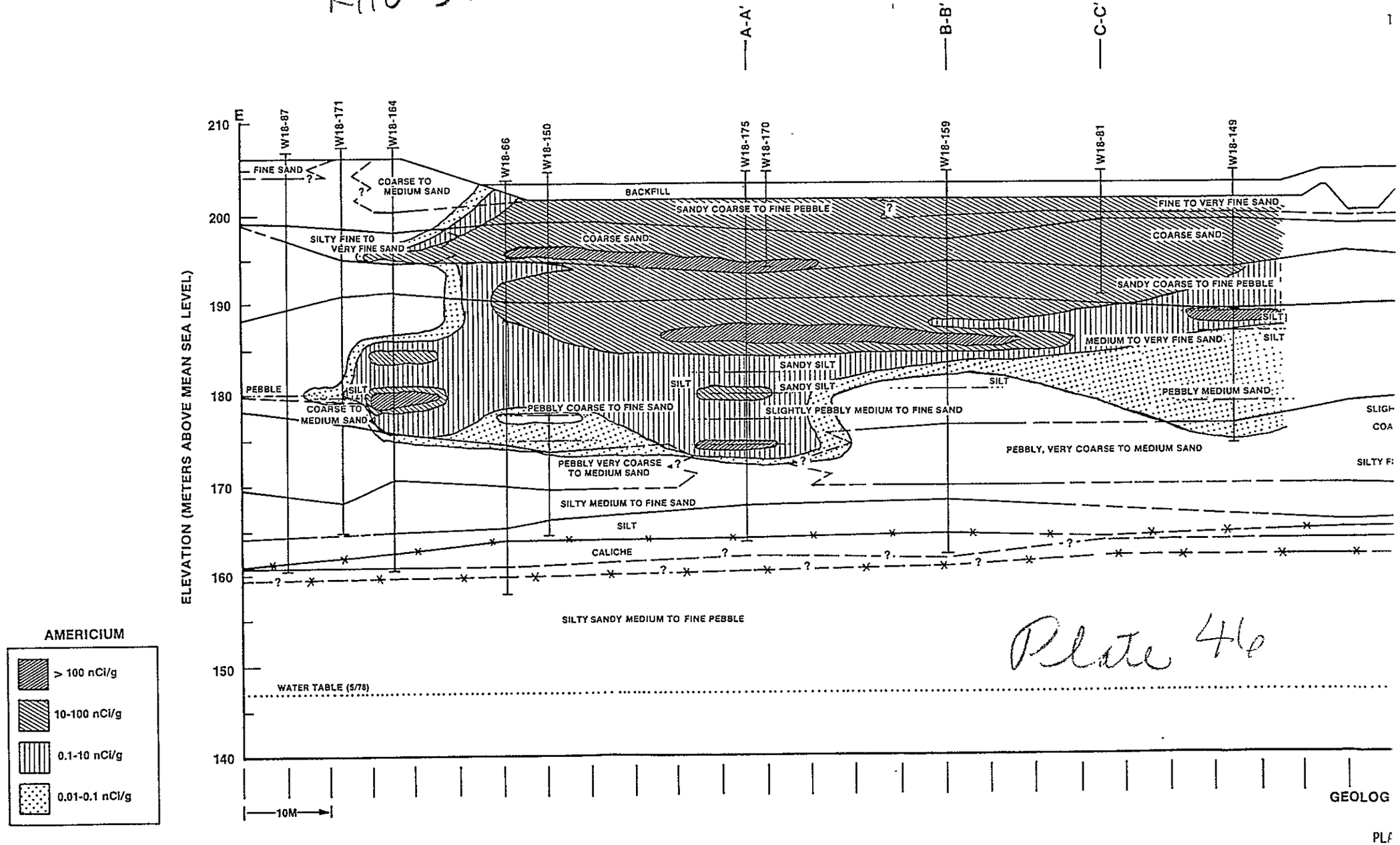


Plate 4b

AMERICIUM

- > 100 nCi/g
- 10-100 nCi/g
- 0.1-10 nCi/g
- 0.01-0.1 nCi/g

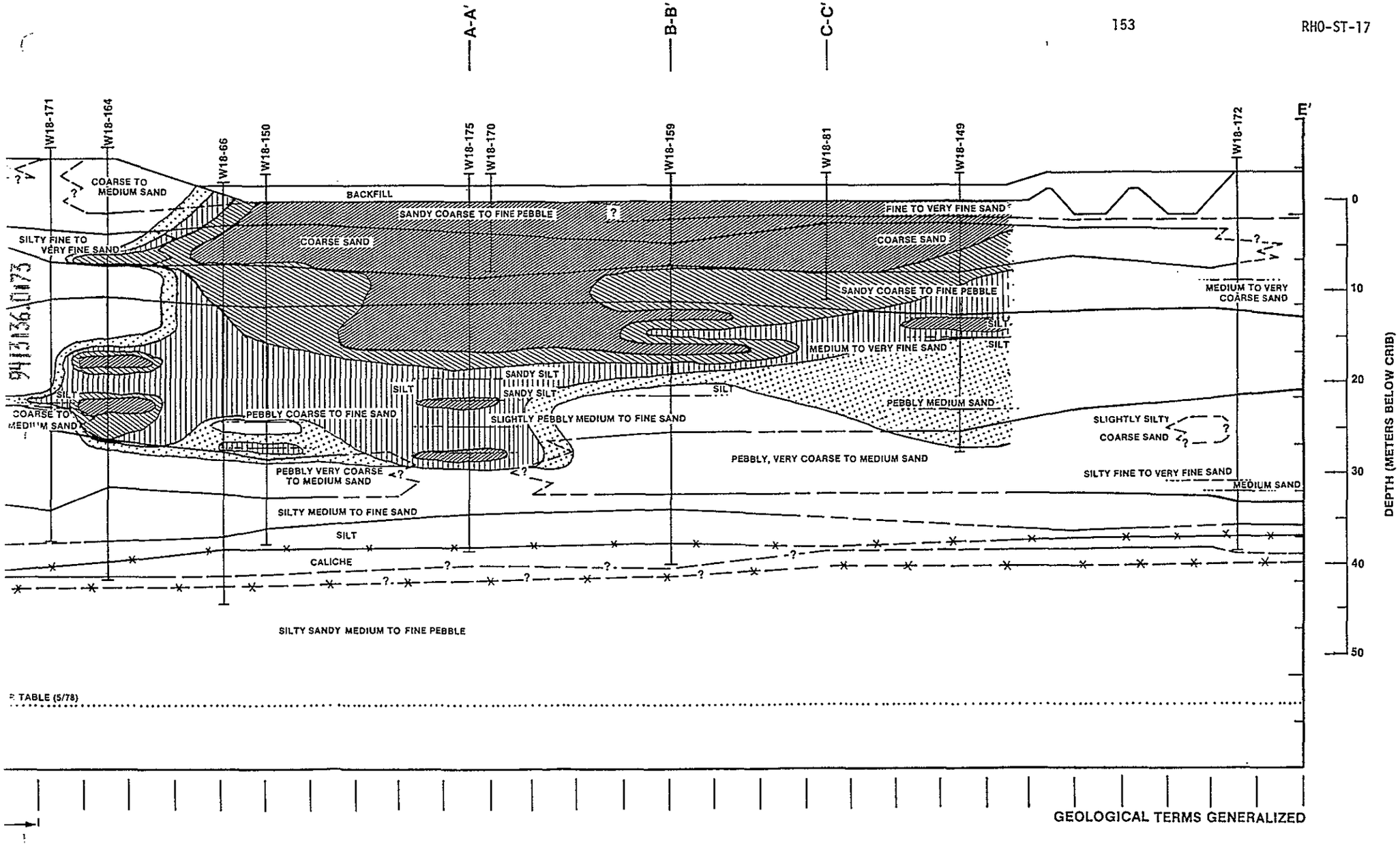
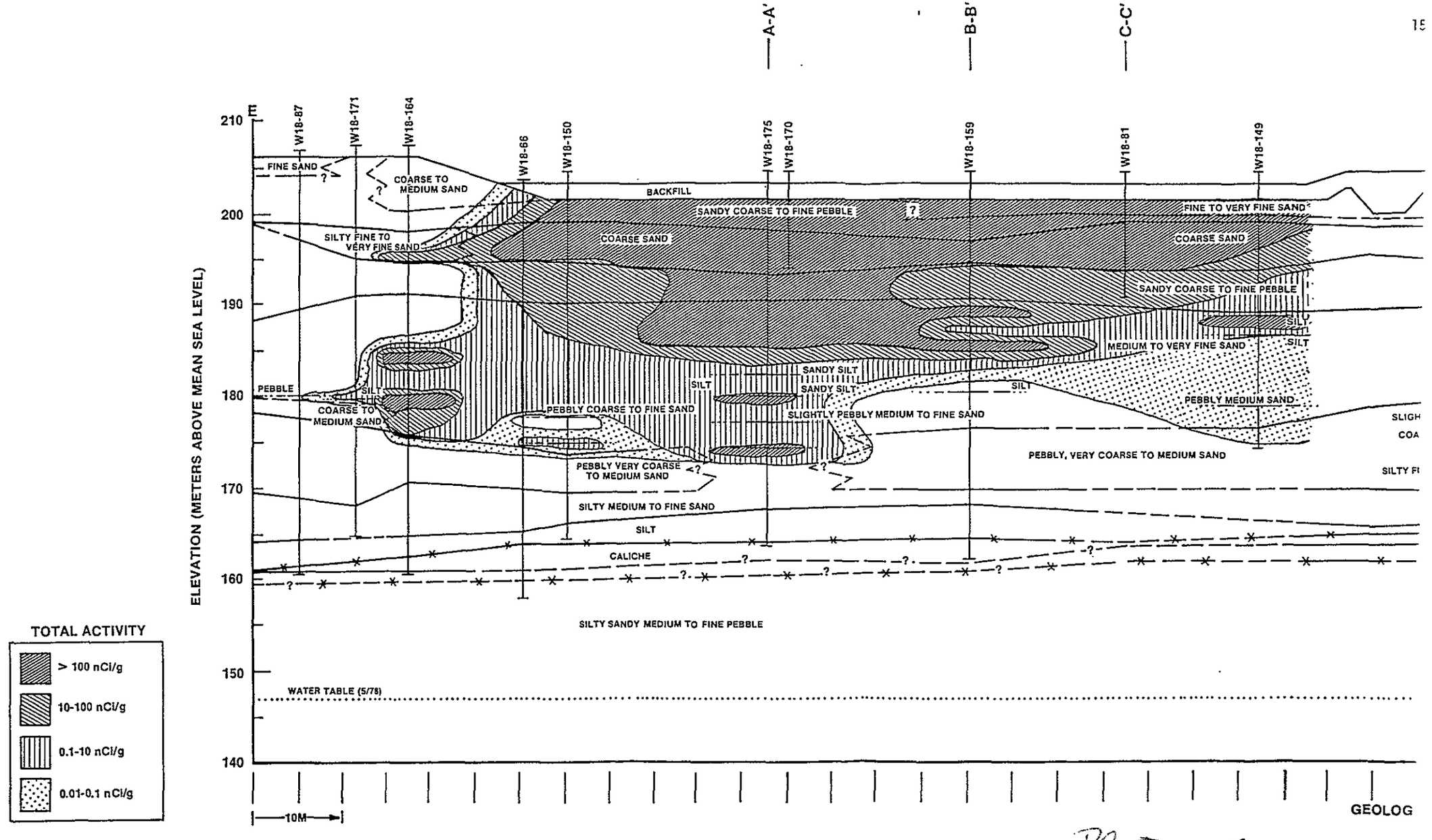

A-A'
B-B'
C-C'
E'
W18-171
W18-164
W18-66
W18-150
W18-175
W18-170
W18-159
W18-81
W18-149
W18-172
COARSE TO MEDIUM SAND
BACKFILL
SANDY COARSE TO FINE PEBBLE
FINE TO VERY FINE SAND
SILTY FINE TO VERY FINE SAND
COARSE SAND
SANDY COARSE TO FINE PEBBLE
MEDIUM TO VERY COARSE SAND
SILT
MEDIUM TO VERY FINE SAND
SANDY SILT
PEBBLY COARSE TO FINE SAND
SLIGHTLY PEBBLY MEDIUM TO FINE SAND
PEBBLY MEDIUM SAND
SLIGHTLY SILTY COARSE SAND
PEBBLY, VERY COARSE TO MEDIUM SAND
PEBBLY VERY COARSE TO MEDIUM SAND
SILTY FINE TO VERY FINE SAND
MEDIUM SAND
SILTY MEDIUM TO FINE SAND
CALICHE
SILTY SANDY MEDIUM TO FINE PEBBLE
TABLE (5/78)
0
10
20
30
40
50
DEPTH (METERS BELOW CRIB)
GEOLOGICAL TERMS GENERALIZED

PLATE 47

RHO-ST-17

Page 153A

9413136.0174



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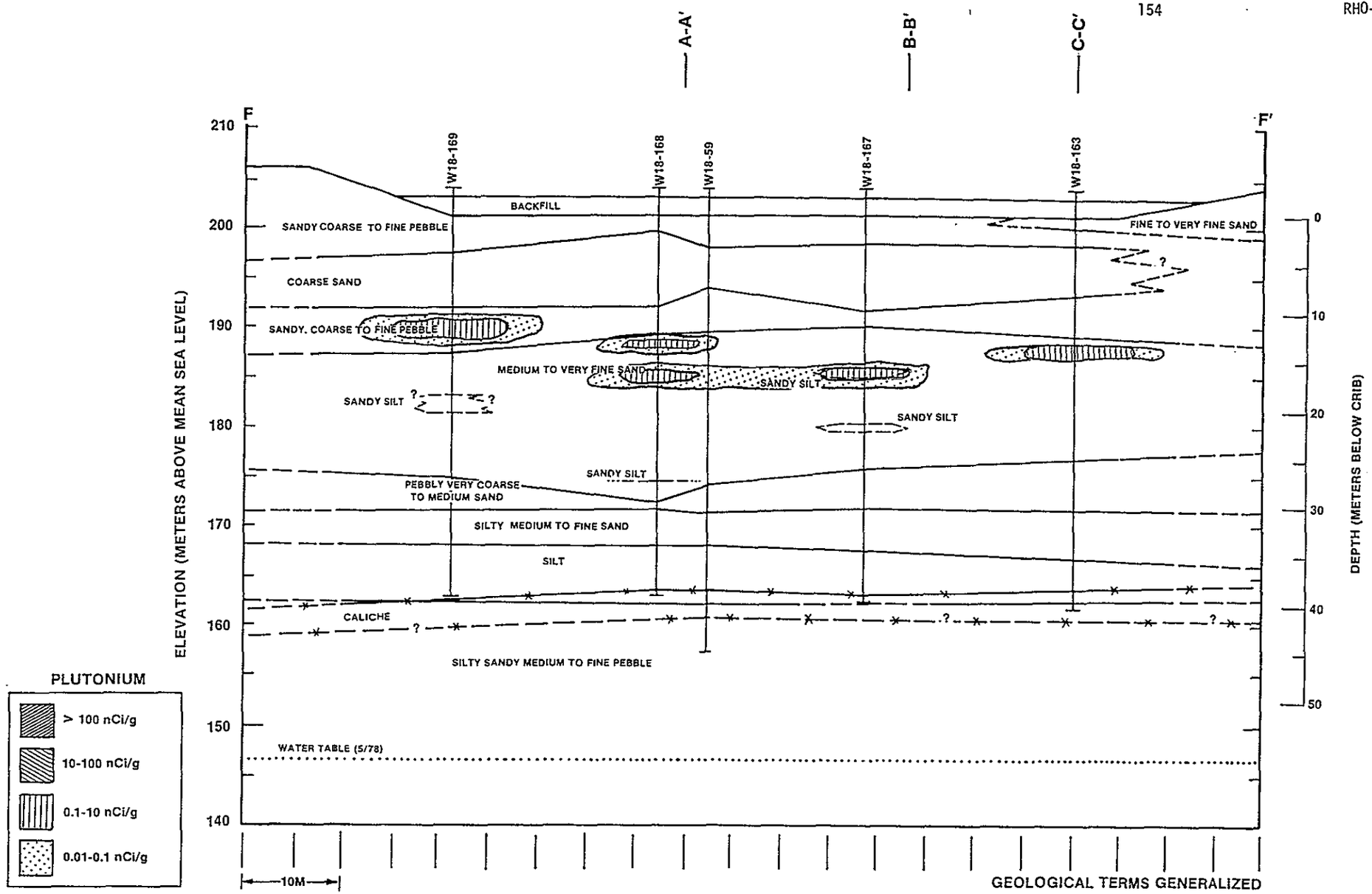

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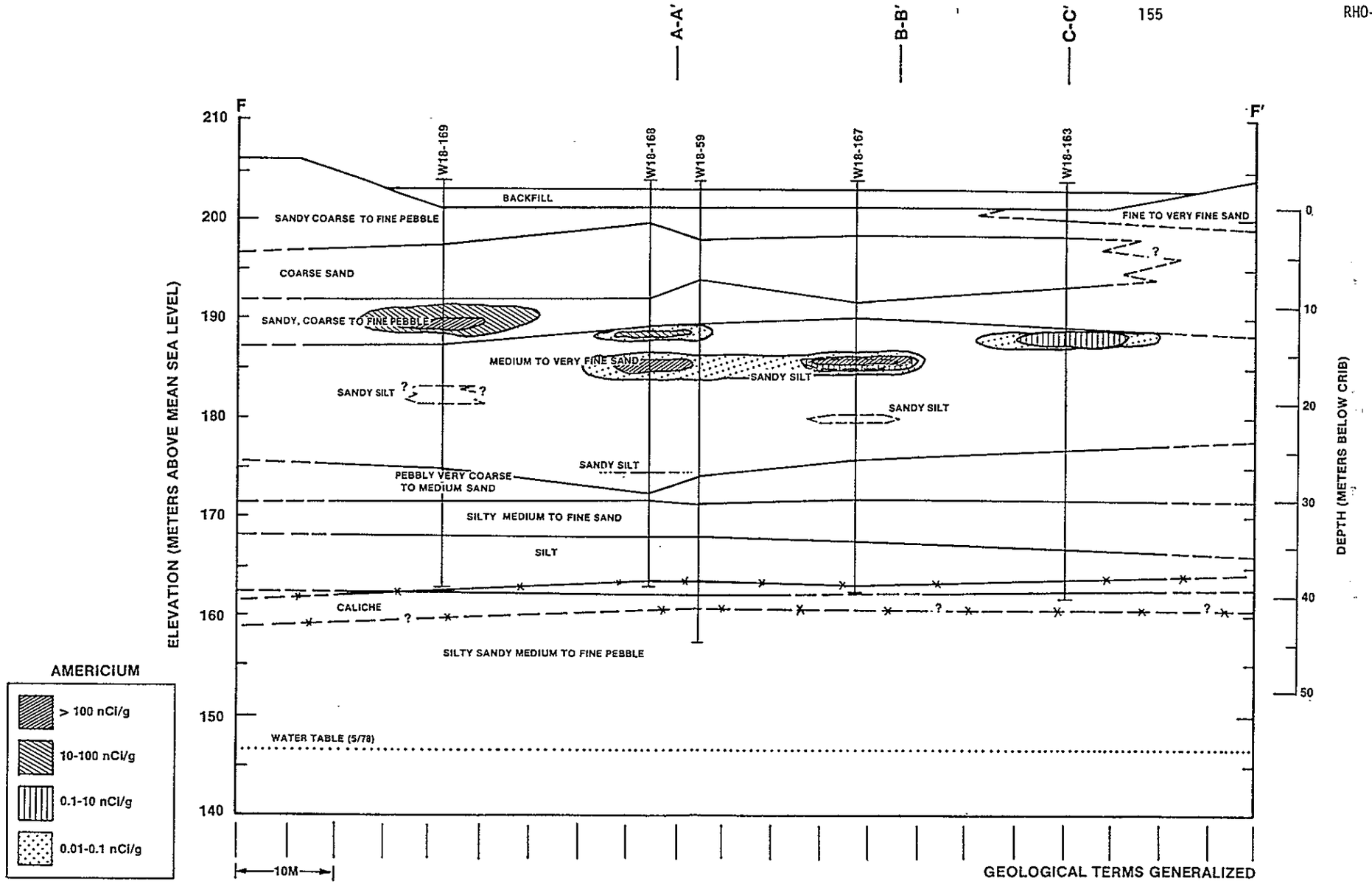

PLATE 49

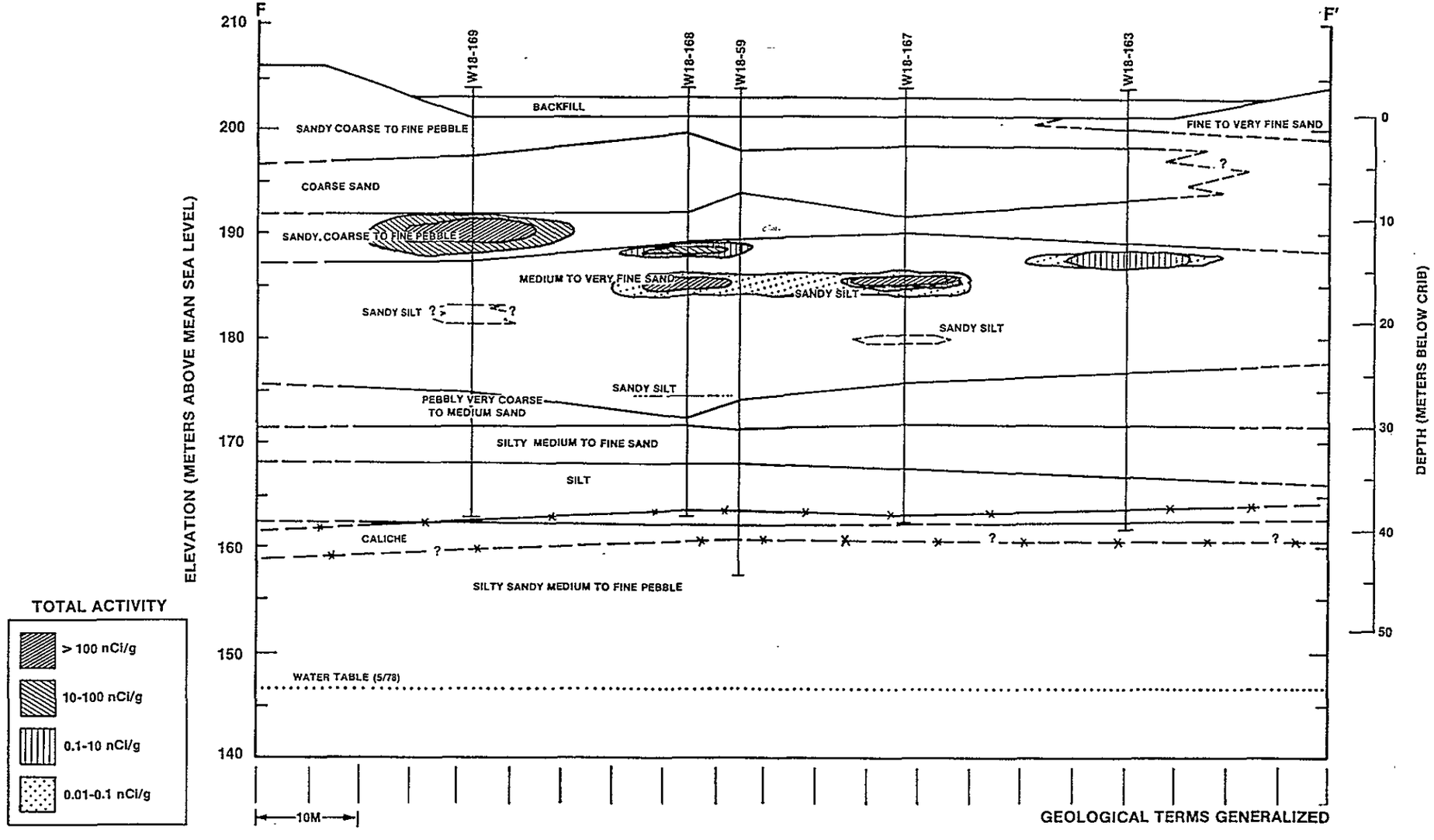

PLATE 50

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